UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Washington, DC 20460

AUTHENTICATION

I, Lynn Vendinello, attest that I am the Director of the Communications Services and Information Division, Office of Program Support of the United States Environmental Protection Agency (EPA) and that the attached documents are true, correct, and compared copies of the file copies in my legal custody, consisting of:

1. December 3, 1986. EPA OPPTS-62036 Docket B6-372: Abex Corp., R. Nelson. American Society of Mechanical Engineers Conference in Washington, D.C. Transcribed conversation with R. Hollander, ICF, Inc. (18 pages). This document is also identified by the following other docket entries:
   - December 3, 1986. EPA OPPTS-62036 Docket B6-381. Ford Motor Co. A. Anderson. American Society of Mechanical Engineers Conference in Washington, D.C. Transcribed conversation with R. Hollander, ICF, Inc. (18 pages).
   - December 3, 1986. EPA OPPTS-62036 Docket B6-386. GM Corp. P Vernia. American Society of Mechanical Engineers Conference in Washington, D.C. Transcribed conversation with R. Hollander, ICF, Inc. (18 pages).
   - December 3, 1986. EPA OPPTS-62036 Docket B6-387: General Motors Inst. S. Gratch. American Society of Mechanical Engineers Conference in Washington, D.C. Transcribed conversation with R. Hollander, ICF, Inc. (18 pages).
   - December 3, 1986. EPA OPPTS-62036 Docket B6-394: Lyndon B. Johnson Space Center. J. McCullough.. American Society of Mechanical Engineers Conference in Washington, D.C. Transcribed conversation with R. Hollander, ICF, Inc. (18 pages).
   - December 3, 1986. EPA OPPTS-62036 Docket B6-395: Massachusetts Institute of Technology (MIT). E. Rabinowicz. American Society of Mechanical Engineers Conference in Washington, D.C. Transcribed conversation with R. Hollander, ICF, Inc. (18 pages).
2. EPA OPPTS-62036 Docket B6-373: Allied Automotive, E. Rogers. Troy, NY. Transcribed telephone conversation with R. Hollander, ICF, Inc. Missing telephone log (5 pages).
3. April 15, 1987. EPA OPPTS-62036 Docket B6-374 (see B2b-10): ASME. Final Report on Analyses of the Feasibility of Replacing Asbestos in Automobile and Truck Brakes. Prepared for ETD, OPTS, USEPA (104 pages).
4. June 27, 1986. EPA OPPTS-62036 Docket B6-375 (see E-20a): Automobile Importers of America. Comments of Automobile Importers of America on Proposed Asbestos Ban Rule (7 pages).
5. June 26, 1987. EPA OPPTS-62036 Docket B6-376: Battelle Columbus Labs, S. Barber. Transcribed telephone conversation with M. Geschwind, ICF, Inc. (3 pages).
6. May 2, 1988. EPA OPPTS-62036 Docket B6-377: Brake Systems Inc., S. Mayo. Transcribed with R. Hollander, ICF, Inc. Missing telephone log (5 pages).
7. October 17, 1986. EPA OPPTS-62036 Docket B6-378: Carlisle, R. Tami. Transcribed telephone conversation with R. Hollander, ICF, Inc. (2 pages).

8. November 4, 1986. EPA OPPTS-62036 Docket B6-379: Chrysler Corp., M. Heitkamp. Transcribed telephone conversation with R. Hollander, ICF, Inc. (1 page).
9. March 26, 1984. EPA OPPTS-62036 Docket B6-380: Design News, S. Scott. "Asbestos Substitutes in Friction Applications" (5 pages).
10. July 2, 1986. EPA OPPTS-62036 Docket B6-382 (see E-46). Ford Motor Co. Comments of Ford Motor Co. on Proposed Asbestos Ban Rule (3 pages).
11. November 19, 1986. EPA OPPTS-62036 Docket B6-384: GM Corp., F. Brookes. Transcribed telephone conversation with R. Hollander, ICF, Inc. (3 pages).
12. June 29, 1986. EPA OPPTS-62036 Docket B6-385 (see E-50c with E-50 and E-50b): GM Corp. Comments of General Motors Corp. on Proposed Asbestos Ban Rule (541 pages).
13. July 21, 1986. EPA OPPTS-62036 Docket B6-396 (see E-92). Original Quality, Inc. Comments of Original Quality, Inc. on Proposed Asbestos Ban Rule (2 pages).
14. October 23, 1986. EPA OPPTS-62036 Docket B6-397 (see N2-15). PEI Associates, Asbestos Product Manufacturers, OTS. Survey of Asbestos OPTS, USEPA (141 pages).
15. November 21, 1986. EPA OPPTS-62036 Docket B6-398: Saab-Scania of America, D. Rainey. Transcription (1 page).
16. December 5, 1986. EPA OPPTS-62036 Docket B6-401: Wagner Corp., F. Hayes. Transcribed telephone conversation with R. Hollander, ICF, Inc. (1 page).
17. July 10, 1987. EPA OPPTS-62036 Docket B6-448: Allied Automotive, B. Bush. Transcribed telephone conversation with M. Geschwind, ICF, Inc. (1 page).
18. July 10, 1987. EPA OPPTS-62036 Docket B6-452: Carlisle, Motion Control Industries Division, R. Tami. Transcribed telephone conversation with M. Geschwind, ICF, Inc. (1 page).
19. November 26, 1986. EPA OPPTS-62036 Docket B6-457: Frieghtliner Corp., T. Robinson, November Transcribed telephone R. Hollander, ICF, Inc. (1 page).
20. October 9, 1986. EPA OPPTS-62036 Docket B6-457.1: Friction Products, D. Cramer. Transcribed telephone conversation with R. Hollander, ICF, Inc. (1 page).
21. October 30, 1986. EPA OPPTS-62036 Docket B6-472: Deere and Co., R. Grotelueschen. Moline, IL. Transcribed telephone conversation with R. Hollander, ICF, Inc. (3 pages).
22. November 20, 1986. EPA OPPTS-62036 Docket B6-492: Borg-Warner, T. Longtin. Transcribed telephone conversation with R. Hollander, ICF, Inc. (1 page).
23. December 15, 1986. EPA OPPTS-62036 Docket B6-500: Mead Corp., L. McDonnold. Transcribed telephone conversation with R. Hollander, ICF, Inc. (1 page).
24. March 26, 1986. EPA OPPTS-62036 Docket B6-501 (see E-102a): Raymark Corp. Comments of Raymark Corp. on Proposed Asbestos Ban Rule (1 page).
25. July 12, 1986. EPA OPPTS-62036 Docket E-8: Arent, Fox, Kintner, Plotkin & Kahn Counsel for Abex Corp. M/C Cover letter with enclosure: (1) Response of Abex corp. to Proposed U.S. Environmental Protection Administration Rule-Proposal of January 23, 1986 (17 pages).
26. June 26, 1986. EPA OPPTS-62036 Docket E-29 parts 1 and 2: Chrysler corp. M/C Cover letter: (1) Comments by Chrysler corp. on Docket Control Number OPTS and (2) Letter from RO Sornsen, Chrysler To TSCA Public Info. Office re: Proposed Prohibition on Use of Asbestos in Motor Vehicle Brake Linings (OPTS-211015) (03/13/85) (8 pages).
27. June 24, 1986. EPA OPPTS-62036 Docket E-35a: Deere & Co. Letter from R.D. Grotelveschen. Plan to provide comments (2 pages).
28. July 3, 1986. EPA OPPTS-62036 Docket E-35b: M/C cover letter for Deere & Co. comments - Docket No. OPTS-62036 Asbestos; Proposed Manufacturing, Importation and Processing Prohibitions (40 CFR Part 763) (1 page).
29. June 26, 1986. EPA OPPTS-62036 Docket E-46: Ford Motor Co. Letter from H. Sussman RE: Asbestos Warning Label for Clutch Plates (3 pages).

30. June 19, 1986. EPA OPPTS-62036 Docket E-58: American Honda Motor Co. Letter from B. Gill M/C cover letter with enclosure: comment of Honda Motor Co., Ltd. Regarding EPA's Proposal to Prohibit the Manufacture, Importation, and Processing of Asbestos in Certain Products and to Phase-out the Use of Asbestos in All Other Products (3 pages).
31. June 30, 1986. EPA OPPTS-62036 Docket E-71: Mercedes-Benz of North America, Inc. Letter from K.H. Faber M/C cover letter with enclosure:Submission of Mercedes-Benz of North America, Inc. to the Environmental Protection Agency (7 pages).
32. May 21, 1986. EPA OPPTS-62036 Docket E-146: Volkswagen of America, Inc. Letter with comments from W. Groth (3 pages).
33. July 16, 1986. EPA OPPTS-62036 Docket J2.2: General Motors Corp. (a) Opening Remarks by Joseph P. Chu, GM Environmental Activities staff. (July 16, 1986), (b) Testimony by Robert L. LeFevre, Manager, Automotive Safety Engineering (July 16, 1986), (c) Closing Remarks by Joseph P. Chu, GM Environmental Activities staff, (d) Statement for the Public Hearing by W.H. Krebs, Director, Toxic Materials Control Activity (14 pages).
34. July 24, 1986. EPA OPPTS-62036 Docket J8.2: Exhibit 1 Motor Vehicle Manufacturers Association. Testimony of Fred Bowditch, Vice President, Technical Affairs (5 pages).
35. November 29, 1984. EPA OPPTS-62036 Docket N1-7a(3) parts 1 and 2: (1) Asbestos Information Assn. letter from E.W. Warren to J.A. Moore and A.J. Barnes Subject: Argument Against a TSCA Ban on Asbestos; Request for Further Meeting with EPA, and (2) General Motors Corp. statement on Asbestos in Brake Systems. (April 17, 1985) (9 pages).
36. March 9, 1988. EPA OPPTS-62036 Docket NN3-5. EPA’s John Rigby and Lynda Priddy Meeting with Representatives of Ibiden Co. Ltd. and Mitsui & Co. (U.S.A.) RE: Asbestos Demand in Japan. John Rigby Memo to The Record (2 pages).
37. October 4, 1988. EPA OPPTS-62036 Docket NN4-15: Telephone Conversation between W. Roberts and T. Buchanan et al, Bendix Corp. Subject: Demand for Asbestos Products in Aftermarket (1 page).
38. October 4, 1988. EPA OPPTS-62036 Docket NN4-16: Telephone Conversation between W. Roberts and B. Tami, Carlisle. Subject: Development of Non-Asbestos Products (1 page).
39. October 4, 1988. EPA OPPTS-62036 Docket NN4-17: Telephone Conversation between W. Roberts and A.C. Dulaney, Standco Industries Subject: Asbestos Brake Products (1 page).
40. October 5, 1988. EPA OPPTS-62036 Docket NN4-18: Memo from W. Roberts to Lear Steigler Corp (1 page).
41. October 10, 1988. EPA OPPTS-62036 Docket NN4-20: Telephone Conversation between M. Wagner and B. Tami, Carlisle. Subject: Brake Blocks (2 pages).
42. October 11, 1988. EPA OPPTS-62036 Docket NN4-21: Telephone Conversation between M. Wagner and J. Shepard, Abex Corp. Subject: Brakes (2 pages).
43. EPA OPPTS-62036 Docket NN4-22: Telephone Conversation between W. Roberts and L. Williams, Raymark Corp. Subject: Friction Products (10/11/88) (1 page).
44. September 8, 1988. EPA OPPTS-62036 Docket NN4-27: Memo from J. Rigby to the record. Subject: July 12, 1988 Meeting between EPA and NHTSA, USDOT Re: Friction Products and NHTSA Rulemaking to Revise Brake Safety Standards (3 pages).
45. September 9, 1988. EPA OPPTS-62036 Docket NN4-28: Memo from J. Rigby to the record. Subject: January 12, 1988 Meeting between EPA and NHTSA [USDOT] Re: Friction Brakes (2 pages).
46. September 9, 1988. EPA OPPTS-62036 Docket NN4-29: Memo from J. Rigby to the record. Subject: July 15, 1988 Meeting between EPA and NHTSA [USDOT] Re: Friction Products Producers (1 page).

47. October 14, 1988. EPA OPPTS-62036 Docket NN4-31: Memo from J. Rigby to the record. Subject: TSCA Phone Logs, Transmittal of 9 Logs, between ICF and Asbestos Friction Product Producers (13 pages).
48. October 12, 1988. EPA OPPTS-62036 Docket NN5-4: ICF, Inc. Telephone conversation between Roberts and Joel Charm, Allied Corporation. Subject: Asbestos Brakes (1 page).
49. October 12, 1988. EPA OPPTS-62036 Docket NN5-5: Telephone conversation between W. Roberts and P. Fried, Champion Auto stores. Subject: Asbestos Brakes (2 pages).
50. October 12, 1988. EPA OPPTS-62036 Docket NN5-6: Telephone conversation between M. Wagner and T. Kovtan, NAPA. Subject: Asbestos Brakes (1 page).
51. October 12, 1988. EPA OPPTS-62036 Docket NN5-7: Telephone conversation between M. Wagner and R. Pittman, Ozark Automotive Distributors. Subject: Asbestos Brakes (1 page).
52. October 12, 1988. EPA OPPTS-62036 Docket NN5-8: Telephone conversation between M. Wagner and J. White, Rayloc. Subject: Asbestos Brakes (2 pages).
53. October 13, 1988. EPA OPPTS-62036 Docket NN5-9: Telephone conversation between M. Wagner and P. Spade, American Auto Parts systems (APS). Subject: Asbestos Brakes (1 page).
54. October 13, 1988. EPA OPPTS-62036 Docket NN5-10: Telephone conversation between M. Wagner and D. Orovitz, Allied Aftermarket, Division of Bendix. Subject: Asbestos Brakes (1 page).
55. October 13, 1988. EPA OPPTS-62036 Docket NN5-11: Telephone conversation between W. Roberts and D. Peterson, Seig-Rockford. Subject: Asbestos Brakes (1 page).
56. October 13, 1988. EPA OPPTS-62036 Docket NN5-12: Telephone conversation between W. Roberts and J. Beasley, TPS, Inc. Subject: Asbestos Brakes (1 page).
57. October 17, 1988. EPA OPPTS-62036 Docket NN5-13: Telephone conversation between M. Wagner and J. Demko, Echlin Corp. -- Brake systems Subject: Asbestos Brakes (2 pages).

Subscribed under the penalty of perjury on this 17th day of May, 2023.

Lynn Vendinello

Lynn Vendinello, Director
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CERTIFICATION OF TRUE COPY

I, Jennifer Clark, certify that I am the Associate General Counsel, General Law Office, Office of General Counsel, of the United States Environmental Protection Agency; that I am the designee of the General Counsel for the purpose of executing certifications under 40 C.F.R. sec. 2.406; that I have duties in Washington, District of Columbia; and that the official whose signature appears above has legal custody pursuant to 40 C.F.R. sec. 2.406 of the original documents, copies of which are attached, as witnessed by my signature and the official seal of the United States Environmental Protection Agency.

Clark, Jennifer

Digitally signed by Clark, Jennifer
Date: 2023.05.18 14:25:15 -04'00'

Jennifer Clark
Associate General Counsel General Law Office
Office of General Counsel

Rick Hollander's notes for the ASME meeting in Washington on 12/3/86

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GET other company names

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November 5, 1986

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REF 386

1

Meeting w/ ASME, 12/3/86

~~List of participants -- get one.~~
- Jeff Hadden @ Battelle gave presentation

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Q's -- Christine's agenda

1. time to replace ea. product, system -- what is appropriate time schedule?
2. grouping of products -- what could replaced at same time or w/in same time frame; what products cannot be replaced in next 10-15 yrs.
3. What is impact of FMVSS 135 -- new standard?

Battelle presentation

- users (use this term instead of consumers in your reports)
- add mineral wool to your list of mineral fibers

substantial development time to reformulate asbestos substitute materials: e.g., semi-metallics took 8 yrs.

but this includes development, re-designing brake systems + testing + validation/qualification of market acceptance + gearing up commercial production

- Abex's main substitute in drum brakelinings is a fiberglass-based drum brake lining
  - Robert Nelson, engineer, Abex Corp. (participant)

also, according to ~~Bendix~~ Ford research guy (~~Bendix participant~~) research in to semi-metallics has been conducted since the 1930s. According to Robert Nelson (Abex) semi-metallics have been marketed domestically for the last 15 yrs.

So, semi-metallics have been around for quite some time.
-- Not a good e.g. of time required to develop new substitutes not yet developed (~~Bendix~~ FORD participant).

MIT prof. says that w/conflict (pressure) (i.e. EPA ban) producers may very well do their best work in developing substitutes -- may take 6 yrs, not 8.

MIT participant) Prof. abinowitz

However, Abex (Nelson) insists rushing the process make compromise safety/performance. Also, all producers are spending great time/effort in R&D now,

in advance of rule promulgation (Steve Shapiro, EPA). (Abex) dirty-wheels (due to binder)

• Discuss technical issues in performance in reports (e.g., fade, wet friction, wear rate, etc.)?
material performance

brake system performance (e.g. stability, noise, vibration, structural integrity, self-actuating force required)

(a) Fed, (b) manufacturer, + (c) customer requirements

(c) is a part ~~[illegible]~~ of (b) though.

~~Bendix~~ FORD says
smaller-sized brakes & some heavy duty air-brakes + hydraulic brakes for trucks there are adequate substitutes ~~[illegible]~~ → OEM only.
intermediate size drum brakes (~~no adequate substitutes available~~) → not true -- he retracts later
~~Bendix~~ FORD has 2 options: wait for more potential substitutes or REDESIGN brakes & lining + this is a major undertaking to revalidate
→ however, still problems here w/ morning sickness + rust/corrosion.

Aftermarket diff. story.

@ parking brake

★ --> Ask ~~Bendix~~ Ford research guy @ substitutes in drum brakes -- which MKT's are they making adequate substitutes + @ aftermarket. --> Why then aren't ~~BIG 3~~ using them in OEM?

- Semi-metallic brake blocks substitute in only severe-braking segment of mkt. because of ~~better~~ good performance in high temp. applications (add to report) (Battelle.)

- best ave. of all friction products is @ 40% by weight asbestos fiber (Abex, ~~Bendix~~ Ford agreed).
- ~~Bendix~~ Ford says optimal level of Kevlar® in brake linings is usu. @ 3% by weight, i.e. a minor component in a formulation. Misleading to say Kevlar®-based or fiber-glass-based products.

- MIT - Prof. Rabinowitz - says exposure risk probably greater in home appliances / commercial machinery (e.g. washing machines, lawn mowers, elevators).

- Abex -- greatest usage in terms of volume of friction materials is <u>automotive</u>

★. Differences between what's happening here + in Europe in friction materials
 - e.g., Europeans live w/ things like reduced wear life + squeal.

- Ford says, specifically in front wheel drive cars:

small cars - brake load is 85% in front, 15% in rear
midsize - brake load is 60% in front, 40% in rear

★ · Availability of testing facilities / capacity in industry -- impact on time schedule for ban/phase-down → for OEM

controversy is in aftermarket. OEM is going along in redesigning systems for asbestos-free materials (← Battelle)

→ Prof. Rabins (Wayne U.)

~~Prof.~~ Other person said testing is a complicated problem; only vehicle / inertial dynamometer tests give good data (correlate well w/ actual vehicle tests) -- these facilities are very expensive.

~~OEM~~ Big producers Abex, Nuturn, Bendix do the expensive dynamometer testing while smaller producers do not (and just for OEM, not aftermkt) -- hard to compete. Very competitive business where producers only concerned w/ costs. If you spend $ on testing, you'll be out of business if you're small. (Ford)

(This latter st. is true of aftermkt mostly).

∴ Cost is primary factor in aftermkt in why substitutes not as great in % replacement

If asbestos-based product are around, aftermkt will not strongly develop substitut — Abex.

Data on substitutes (received by ICF + EPA) is anecdotal, expert judgement type qualitative data. Could use more quantitative data to pin this down.

BRAKE BLOCKS!

- Abex says for the most part -- even in truck fleets (where brake jobs are quite expensive) fleet owners care more @ cost/price of brake lining than performance / service life. So ~~then~~ for the most part, fleet owners wouldn't be willing to pay more for substitutes w/ greater service life (i.e., high up-front cost, but comparable present value over svc life).

Key point for aftermarket.

- NASA guy says if ban placed on aftermarket, then there will be an economic incentive to produce retrofit substitutes (i.e., aftermarket) -- price of the product will go way up → ∴ econ. incentive --> although the prices of these products may be prohibitive.

★ (and timing to gear up production (+ ~~any~~ capital conversion, etc.)

- GM (Mr. Vernia) said substitutes are avail in drum linings (^cars + light trucks) (OEM) but less for med. light cars + trucks → however reason why automakers still don't consume very much is because field testing for validation ★ hasn't occurred yet (even though dynamometer testing has been done). This principal substitute according to Vernia is a blend of steel wool, Kevlar, and/or mineral fibe

Contradicts what Thomas Johnson @ GM said! change in your report?

Ford:
problem w/ non-asbestos products is changes in temp can bring on inordinate changes in brake torque produced by lining w/out any advance warning to driver

$\boxed{\text{WHICH materials? which types of brakes?}}$

Ford/Abex -

why might not want to do away with drum brakes:

- parking brake -- drum brake is superior to disc brake (drum brakes work better @ lower temp. than semi-met disc) ← asbestos
- cost .. drum brakes more economical in rear than disc

But in auto. trans cars, can just put in park, however, FMVSS 105 - (stopping distance test) requires a friction parking brake! - Abex/Ford

$\boxed{\text{15\% of LMV's in U.S. today are manual transmission -- Ford --> but trend according to Abex, is towards more manual transmission.}}$

Ford:

you don't have to have same performance. Drivers will accept changes in performance, just no surprises that reduce safety. No substitutes which take ~~care of all~~ provides all the advantages asbestos did, but the point is there are acceptable substitute for some drum brake lining applications.

FOR OEM ONLY!

Fed regi's (FMVSS): standards for stopping, fade, recovery, wet friction!
105, 121 &
proposed 135 + (136?)

Abex.

this isn't field testing (i.e. in diff. regions of country under actual conditions)

Lab/vehicle testing is only ~~for OEM manufacturers.~~
Aftermkt manufacturers are almost totally lacking in equip. testing.

FORD

All for OEM; There are No Standards (federal regulations) for aftermarket! — All agreed (Abex, Ford, etc.

• According to GM + Ford, ~~[illegible]~~ given where we are now in replacing asbestos in OEM LMV's, there are adequate dynamometer/vehicle testing facilities to test substitutes for OEM so that in 5 years can ban asbestos in brakes in the OEM in LMV's.

☆ What @ clutch facings?

• In addition to some performance advantages, also marketing advantages to why front disc brakes put on OEM LMV's

Ford

originally, the sports car mfr.'s were buying them & car mfr's found out that disc brakes ~~[illegible]~~ were selling cars. Disc brakes, however, reduce fuel economy because of "parasitic drag." Disc brakes much higher cost (because of mechanical system) than drum brakes — Modify your reports slightly.

— 12/4/86 —

The good manufacturers of friction products, generally, are OEM and aftermarket (Ford).

Abex — probably 5-6 of them use vehicle/dynamometer tests -- rest do not!

Abex has 2 rear/drum brake materials: non-asbestos

- one of which is semi-met

Ask Abex more @ this.

also make a non-asbestos, non-semi-met front disc brakes to go along w/ non-asbestos drum

several potential advantages of these disc brakes over semi-metallics.

Problems w/ rear semi-met disc brake pads

Must redesign systems for semi-met disc brake parking brake → doesn't work w/o some extraordinary redesign of system.

Not sure @ this comment

Again, rear brakes don't have to do as much work -- not as critical.

trend towards 4 disc brakes in LMV's:

ok - drum brakes are lower cost / more economical and performance advantages because make better parking brakes. But from a marketing standpoint, disc brakes ~~[illegible]~~ make cars sell and so these are used more.
Ford says the trend is toward 4 disc brakes in domestic cars: 4 disc brake systems may have slightly better performance

→ Abex, + Serge Gratch (GMI) disagree. Just a few car companies have started this, but this is not at all the trend — would require enormous equipment redesign, + 4 disc brake systems are not better performance-wise for all applications

p 78: experts disagree:

- fiberglass is close to asbestos fiber in cost

Brake Blocks

- fiberglass used mostly in OEM drum brake linings + brake blocks

→ Abex says improved wear, @ 25% increase in cost of asbestos.

Fiberglass, says, Abex is not any more abrasive than asbestos on drums; overall fiberglass drum linings, brake blocks are cost-effective for the above reasons.

Brake Blocks

FORD:

3 types of substitute in brake linings!

1. full-sintered metallic (no resin)
2. semi-metallic (resin bonded)
3. non-asbestos organic (fiberglass, Kevlar, mineral fibers, perhaps some steel wool, fillers + resins)

(NAO's)

Completely misleading to call this 3rd category fiberglass or Kevlar linings, as these account for only small % of total formulation

Abex, in OEM, "is at @ 50% asbestos-free in all of their friction products.

Abex states that they have good OEM drum brake linings (light trucks, medium trucks, heavy trucks + cars) for which the chief fiber is fiberglass -- that have ~~effect~~ better wear than asbestos so are cost-effective (25% higher cost on ave. than asbestos-based). Abex is also producing these linings + blocks for the aftermarket for REPLACEMENT OF ASBESTOS LININGS -- doing fine they said - Abex

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others disagree - i.e., that this is actually not good to replace in aftermkt.

so not clear that adequate OEM substitutes are not available.

- production timing problems
- insufficient field testing (though adequate dynamometer + vehicle testing)
- redesigning brake systems

still rel. low % of consumption by automakers

167:

According to Abex + Ford --

$\boxed{\text{processing}}$ problems w/ semi-met

in thin ~~thi~~ segments -- i.e. drum linings

for LMV's -- more of an art w/ thin segments

+ semi-mets don't lend themselves to this

processing of these products ∧ less of an

art in thick segments -- brake blocks +

semi-mets are used for severe braking applications

-- logging + mining trucks.

Also functional (performance problems) -- morning sickness -- moisture gets in overnight + product is useless until heats up + dried out) unacceptable to all participants

problem is worse w/ semi-met drum brakes

all Semi-metallics: steel wool contain (% contents vary) sponge iron graphite powder resin fillers/additives

Ford

So the fiberglass-based, other NAO's +

GM's chopped steel wool, fiberglass, Kevlar,

mineral fiber blend (GM's product

is hybrid blend -- neither semi-met or NAO

exclusively).

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GM + Abex agreed:
Semi-mets are not less abrasive than asbestos -- can be more abrasive. (DuPont agreed in telephone interview/public comments)

so disagree w/ p. 66

DON'T USE THIS FIGURE

~~1985 Ward's Automotive said 33% of 1984 imported cars had disc brakes on rear~~

Not good, all agreed

however, all the experts totally disagree (MIT said more like 0.33%!)

100% of imported rear disc or drum brakes were ASBESTOS-BASED in 1985

FORD

Abex: small producers of brakes are not active in R&D + getting info -- participating in meetings w/ FMSI (for e.g.) -- it's the big producers doing all the research + sponsoring colloquia

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foundation brake = brake assembly

→ Wagner no longer in this mkt says Abex, supply brake parts + linings only (ECR -- do not mfr. linings) -- p. 87

p89: Not true, GM does make non-asbestos drum brake linings.

Appendix C: Ford -- Ford guy + Abex vehemently disagree -- no substitutes for these

Conclusions: entire group agreed:

Railroad brake blocks are now all non-asbestos (FORD)

basically, just some high-friction applications that do not have substitute available

- some heavy trucks
- some heavy vehicles

or at least are not all near to production; not that they couldn't be developed.

Industry is progressing well towards producing substitutes (friction material producers + automakers)

★ The time element really is system re-design for non-asbestos friction materials. Systems can be redesigned (e.g. servo systems, etc.).

Note: Motorcycles, like cars, typically use disc brakes in front w/ drum brakes in rear (Abex + D.O.T.)

Absolutely certain substitutes will be found for the large majority of asbestos-based friction products.

says the group.

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62036
B6-373

ICF INCORPORATED

RIA 373
404
434
447

May 2, 1988

MEMORANDUM

TO : The Record

LOG 2282

FROM : Michael Geschwind
Peter Tzanetos
Frank Arnold

RIA
373
404
434
447

SUBJECT : Missing Telephone Logs for the Asbestos RIA

This memorandum discusses the nine missing telephone logs mentioned in the April 26th memorandum to Christine Augustyniak and Joni Repasch. After analyzing the RIA, we have concluded the following non-CBI information was based on each telephone log:

1. Ertel Engineering (Reference #175)

Ertel Engineering discontinued the use of asbestos in the production of paper filters in 1985.

2. Marley Cooling Tower Company (Reference #180)

Marley Cooling Tower Company no longer manufactures asbestos fill for cooling towers in the United States. Several products available as substitutes for asbestos cooling tower fill have limited application due to specific disadvantages. Wood is not an adequate substitute because it is not economically feasible to manufacture it in the sheet forms required for cooling tower fill. Portland cement reinforced with mineral and cellulose fibers is presently under development as a substitute, but currently is only available in limited shapes and at high cost.

3. Allied Automotive (Reference #373, 404, 434, and 447)

In light and medium vehicles, the lining segments of drum brakes are usually a third of an inch thick or less and are called drum brake linings; however, in heavy vehicles such as heavy trucks and off-road vehicles, the drum brake linings are at least three-quarters of an inch thick and are called brake blocks instead of drum brake linings.

Brake linings are either bonded (glued) or riveted onto the brake shoe. Bonded brake linings have greater frictional surface area than riveted linings, but riveted linings are quieter.

Allied Automotive has two plants, one in Cleveland, TN and the other in Green Island, NY, both of which manufacture asbestos and non-asbestos drum brake linings. Allied Automotive also produces semi-metallic drum brake

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linings.

Asbestos drum brake linings account for approximately 90-95 percent of OEM sales and almost 100 percent of aftermarket sales.

Allied Automotive estimates that 18 percent of its 1986 drum brake lining production will be non-asbestos. Producers of brake linings are highly averse to the risk that could be associated with new substitutes. The risk is magnified when a major brake system redesign is required for a substitute lining.

Semi-metallic disc brakes are already used on the front wheels of 85 percent of all new light/medium vehicles. Furthermore, some luxury import cars are now equipped with four semi-metallic disc brakes.

Replacement of asbestos-based drum brake linings in the aftermarket is much more difficult than in the original equipment maarket (OEM). Brake systems designed for asbestos lining should continue to use asbestos linings. Substitute lining formulations that are designed for the OEM, when used to replace worn asbestos linings, do not perform as well as asbestos and could jeopardize brake safety.

Disc brake pads are either bonded (glued) or riveted onto the steel plate in a disc brake. Bonded disc brake pads have greater frictional surface area than riveted pads, but riveted pads are quieter.

Semi-metallic disc brake pads are molded products containing chopped steel wool, sponge iron, graphite powder, fillers, and resins. Some semi-metallic pads contain a very thin asbestos-containing backing, or underlayer, between the steel plate and the pad. Other semi-metallic pads have no underlayer or have one made of a non-asbestos material. The underlayer acts as a thermal barrier between the pad and plate, and helps to bond the pad to the plate. Producers of disc brake pads generally do not consider semi-metallic pads with the asbestos underlayer to be asbestos pads because the lining itself contains no asbestos and the underlayer is only a very small percentage of the total content of the pad. Substitutes for the thin asbestos underlayer in some semi-metallic pads include either no underlayer or a chopped fiberglass or Kevlar(R) underlayer, depending on the application. The substitutes for the asbestos underlayer perform just as well as the asbestos underlayer.

Semi-metallic disc brake pads perform better at higher temperatures than asbestos-based disc brake pads and have a longer service life. In general, at lower temperatures asbestos-based pads perform better than semi-metallics, and are quieter. Front-wheel drive vehicles, which have greater brake load in the front (and thus generate more brake heat in the front) than real-wheel drive vehicles, exclusively use semi-metallic disc brakes in the front.

Currently, asbestos probably holds no more than 15 percent of the OEM for disc brake pads for light/medium vehicles, and the balance (85 percent) is nearly all semi-metallics. By 1990, asbestos will be almost completely replaced in the disc brake pad OEM, given the trend towards 100 percent front-wheel drive light/medium vehicles.

Replacement of asbestos pads in the aftermarket is much more difficult than in the OEM. Brakes systems designed for asbestos pads should continue to use asbestos. Semi-metallic pads which were designed for the OEM, when used to replace worn asbestos pads, do not perform as well as asbestos, and could jeopardize brake safety.

Three primary reasons for little or no development of substitutes engineered for aftermarket brake systems that were designed for asbestos:

- developing adequate substitutes for a system designed specifically for asbestos involves considerable technical difficulty;

- no federal safety and performance standards exist for brakes for the aftermarket; and

- producing and testing substitute formulations is very expensive.

Disc brake pads (asbestos and non-asbestos) for heavy vehicles are a small and relatively new market. Although disc brake pads were a small percentage of heavy vehicle brakes in the past, these systems are increasingly common for heavy vehicles. Except for the larger size, disc brake pads for heavy vehicles are similar to those described for light/medium vehicles. To date, disc brake pads for heavy vehicles are only used on the front wheels of certain intermediate-sized trucks, 12,000-22,000 lbs. per axle. They can never be used for the heaviest trucks.

Although non-asbestos semi-metallic pads have nearly always been used for disc brakes for heavy vehicles in small proportions, in the past asbestos-based pads were used to a greater extent. Asbestos disc brake pads for heavy vehicles are now only used to replace worn asbestos pads in the aftermarket. The switch to semi-metallic pads from asbestos pads is due to the high braking temperatures generated in this application. Semi-metallic pads have superior performance and service life at high temperatures.

Semi-metallic pads for heavy vehicles are made with the same ingredients as those for light/medium vehicles and also may be made with or without an underlayer.

Allied Automotive currently only produces semi-metallic disc brake pads for heavy vehicles. 100 percent of the OEM and most of the aftermarket is held by the semi-metallic pads. The cost of the semi-metallic pad is approximately $12.50 per piece.

Brake blocks are brake linings used on the drum brakes of heavy vehicles -- heavy trucks, buses, and heavy off-road vehicles. Heavy trucks range from moderately heavy, 12,000 -22,000 lbs per axle to very heavy, i.e., tractor trailers and logging and mining trucks. The heavy-vehicle drum brake consists of two curved metal "shoes" to which brake blocks are attached. Each shoe has two blocks, a longer one (the anchor) and a shorter one (the can), resulting in a total of four blocks per wheel. Each block is at least three-quarters of an inch thick and covers 50° to 60° of the arc around the wheel. Each block is riveted to the brake shoe.

Drum brakes for heavy vehicles are either air- or hydraulic-activated, depending on the application. Tractor trailers always use air brakes and medium-sized trucks normally use hydraulic brakes.

Allied Automotive is a relatively small manufacturer of brakes blocks, producing only for the severe braking applications segment of the market (i.e., logging and mining trucks). Allied produces both asbestos and non-asbestos brake blocks in its Cleveland, TN plant.

For the vast majority of applications, i.e. heavy trucks and off-road vehicles, excluding the super-heavy applications (logging and mining trucks), the major group of substitutes are the non-asbestos organics (NAOs). The major substitute for the super-heavy applications, which represent a very small share of the total market, is the full-metallic block.

Allied is in the process of developing a non-asbestos, non-full metallic block. NAO brake blocks have equivalent or superior performance and improved service life relative to asbestos blocks. Allied produces full-metallic brake blocks. These have improved performance over asbestos for extremely high temperature ranges, and they have twice the service life of the asbestos blocks. The price of Allied's full metallic brake block is 83 percent more than the price of its premium asbestos product.

In the event of an asbestos ban, NAO brake blocks will capture the majority of the asbestos-based OEM. The choice of replacement in the aftermarket is more difficult to estimate. Brake systems designed for asbestos brake blocks should continue to use asbestos. Substitute linings which were designed for the OEM, when used to replace worn blocks, do not perform as well as asbestos, and could jeopardize brake safety.

4. <u>Brake Systems (Reference #377, 406, and 435)</u>

Brake Systems Inc., a division of Echlin, purchased Raymark's Stratford, CT drum brake lining plant. Brake Systems also owns Echlin's Dallas, TX plant that was formerly owned by Raymark. The Echlin plant in Dallas, TX is a secondary processor where linings are attached to brake shoes without any additional processing.

Brake Systems also produces NAO drum brake linings.

Brake Systems purchased Raymark's Stratford, CT disc brake pad (LMV) plant. Brake Systems also produces a non-asbestos disc brake pad (LMV) at this plant. Brake Systems produces non-asbestos organic (NAO) pads as substitutes for the asbestos pads but did not indicate it produces them in a sizable quantity.

Brake Systems only manufactures semi-metallic disc brake pads for heavy vehicles at their Stratford, CT plant. This semi-metallic pad contains a very small asbestos underlayer, however Brake Systems does not consider this an asbestos disc brake pad. Brake systems does not manufacture asbestos disc brake pads for heavy vehicles.

5. Wheeling Brake Block (Reference #468)

Wheeling Brake Block in Bridgeport, CT phased out its production of asbestos brake blocks in 1986. The firm currently manufactures non-asbestos brake blocks. These include non-asbestos organics and full-metallic blocks. Wheeling Brake Block only produces their full-metallic blocks in limited quantities and in the past they have generally had poor performance compared to asbestos blocks. However, they have been changing this product recently.

6. Department of Transportation (Reference #659)

This reference was not used in the text and will be deleted from the reference list in the May RIA.

7. Essex Specialty Products (Reference #661)

Essex Specialty Products expects a significant decline in the asbestos extruded sealant tape market over the next several years due to the development of cost effective substitutes, particulary in the area of automotive applications.

Essex produces structural urethane, a major substitute for asbestos sealant tape. It is used to seal automobile windshields and has the a largest share of the market for windshield sealers, 90 percent of the domestic OEM and 60 percent of the aftermarket. Essex expects the market share of the structural urethane to increase and considers structural urethane to be capable of replacing 100 percent of the windshield sealer market. Structural urethane is expected to last 20 years. Its main advantages relative to other sealers are its strength (sheer strength is 700-800 psi) and its lower cost.

8. MB Associates (Reference #666)

Due to the development of cost effective substitutes, there will be a significant decline in the asbestos extruded sealant tape market over the next several years.

9. Parr Incorporated (Reference #667)

Parr Incorporated produces cellulose-fiber tape as a substitute for asbestos sealant tape. Parr's tape is sold primarily for sealing windows on mobile homes and recreational vehicles (RVs). It is less expensive than asbestos tape, however it is not as strong or as heat resistant, and it has a shorter service life. Its service life is fifteen years, and the service life of the asbestos product is 20 years.

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FINAL REPORT

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on

ANALYSIS OF THE FEASIBILITY OF REPLACING ASBESTOS IN AUTOMOBILE AND TRUCK BRAKES

Prepared for the

Environmental Protection Agency
OPTS, ETD
April 15, 1987

by

The American Society of Mechanical Engineers

Subcontracted by
major contract Battelle
Columbia

Rec'd 6/24/87

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

FOUNDED 1880

This is a report of an expert panel assembled by ASME to address the technical issues associated with the removal of asbestos from vehicle friction products. This panel convened on December 3 and 4, 1986, to discuss issues of vehicle safety, friction material availability and performance, and future trends in the development of asbestos-free friction products.

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EXECUTIVE SUMMARY AND CONCLUSIONS

Due to reported health problems associated with the use of asbestos, the Office of Toxic Substances has proposed a regulation to ban the use of asbestos over a 10-year phase-down period. Since asbestos is currently a critical constituent in some vehicle friction products, the Environmental Protection Agency is interested in determining whether the proposed ban could have adverse effects on vehicle braking safety.

In order to assess the potential effects of the proposed ban on vehicle brake system operation and vehicle safety, a panel of individuals knowledgeable in the various aspects of vehicle brakes and friction materials was assembled by the American Society of Mechanical Engineers (ASME). The panel addressed technological issues associated with the removal of asbestos from friction materials, specifically:

(1) Identification of substitute brakes and systems,

(2) Compatibility of the ban with motor vehicle safety standards,

(3) Problems associated with replacing asbestos friction materials in aftermarket vehicles, and

(4) Pace of research and commercialization and effects on phase-out.

This report addresses the technical issues related to the proposed ban considered by the panel to be the most important.

Conclusions

Identification of Substitute Brakes and Systems

Vehicle controllability during braking is affected by both driver and brake system performance. Generally, vehicle front-to-rear braking ratios are adjusted on a per-model basis to provide optimal braking. Too much braking on an axle results in premature wheel lock-up, and this can lead to loss of steering control (front lock-up) or spin-out (rear lock-up). While the effectiveness of disc brakes is directly proportional to pad-disc friction levels, the effectiveness of drum brakes can be greatly affected by changes in lining-drum friction. Friction materials that exhibit reduced effectiveness also can result in brakes having insufficient torque needed to stop the vehicle. Different drum brake designs exhibit dramatic differences in effectiveness.

Because disc brakes maintain effectiveness at high braking speeds, 4-wheel disc brakes have been used in the past on high performance European vehicles designed to operate at high speeds on unregulated European highways. This is one reason behind the European use of 4-wheel disc systems. In addition, non-asbestos drum brake materials for automobile drum brakes have been difficult to qualify in the past. For these reasons, several European automakers use 4-wheel disc brakes in conjunction with semimetallic pad materials as a means of eliminating asbestos.

The majority of the automobiles sold in the United States now are fitted with front disc brakes and rear drum brakes, and this trend will most likely continue for some time. Because of differences between qualification standards, cost, driver preference, and driving conditions in the United States and Europe, American and Japanese automakers are utilizing rear drum brakes. Suitable non-asbestos materials are not available for all of these applications, and industry-wide substitution of non-asbestos materials in all existing brake designs would require considerable development. It is unrealistic to assume that all automakers will redesign all passenger car and truck braking systems around disc brakes in order to utilize semimetallic materials.

Compatibility of the Ban With Motor Vehicle Safety Standards

The qualification of original equipment braking systems is regulated under Federal Motor Vehicle Safety Standards (FMVSS) 105 and 121. For many original equipment manufacturers, these requirements represent minimal standards of performance, and supplemental qualifications are usually satisfied due to customer demand. Satisfactory compliance with FMVSS 105 and 121 requires vehicle and inertial dynamometer test facilities to evaluate brake system performance on a per-model basis. To test compliance with these requirements, vehicle manufacturers submit braking systems and friction products to numerous levels of qualification tests. No simple bench-top tests are available to evaluate the performance characteristics of friction materials or to demonstrate their compliance with Motor Vehicle Safety Standards. Results obtained using scaled-down laboratory apparatus, such as friction material testing machines (FMTM) or friction assessment screening test (FAST) machines, have been shown to correlate poorly with vehicle test results. The performance of aftermarket friction materials is not regulated by law.

In comparison with current federal safety standards which specify required stopping distances and deceleration, the proposed FMVSS 135 for passenger cars and light trucks will require front braking bias in the event of a wheel lock-up during braking. This situation requires that the front wheels lock-up before the rear wheels.

The adoption of FMVSS 135 and the failure to qualify rear brake drum linings exhibiting consistent levels of friction over a wide range of performance conditions may affect the design philosophy of American and Japanese automotive engineers. Forced to ensure front bias in the system, automakers may move to using less effective disc brakes on the rear and increasing the front-to-rear braking ratio to ensure consistent performance, if proven rear lining materials are not found.

Problems Associated With Replacing Asbestos Friction Materials in Aftermarket Vehicles

The substitution of unqualified non-asbestos friction materials in the aftermarket poses the largest potential safety issue. Because vehicle controllability during braking is strongly affected by friction material performance, unqualified substitution of friction materials in either vehicle disc pads or drum linings may have an adverse effect on vehicle brake balance and controllability. A large number of older vehicles in the United States have brake systems designed for asbestos friction products. The use of unproven materials in place of proven asbestos materials in existing systems could result in a loss of vehicle controllability during braking.

Currently, there are no required performance tests for aftermarket brake friction materials. In addition, most of the aftermarket, non-asbestos material suppliers lack the facilities to evaluate their materials under dynamometer and vehicle braking test conditions.

Non-asbestos friction materials that have been developed to date have provided some new and unexpected failure modes and mechanisms due to their unique combinations of new raw materials and manufacturing processes.

Mandating aftermarket non-asbestos friction materials for vehicles that were originally equipped with asbestos-based linings could lead to a potentially serious customer safety risk, unless stringent friction material qualification specification tests are included.

Pace of Research and Commercialization and Effects on Phase-Out

Non-asbestos friction material technology is advancing rapidly. Several new asbestos-free car, light truck, and heavy vehicle brake systems have been released for OEM applications in the past 3 years. More new vehicle brake systems will be released with non-asbestos friction materials for the 1988 model year.

Adequate non-asbestos friction material formulations presently are not available for all vehicle systems. However, at the present rate of technical progress, most new passenger cars could be equipped with totally non-asbestos frictional systems by 1991, and most light trucks and heavy trucks with S-cam brakes, by 1992. However, a few low-volume new vehicle applications may not have acceptable non-asbestos friction materials at that time. Heavy truck wedge brake blocks, medium truck drum brake linings and many off-road vehicle brake linings may not be developed by 1992.

New classes of non-asbestos friction materials have unique compositions which may have unexpected failure mechanisms. In many cases, unique failure modes are revealed only through extensive vehicle testing.

Numerous automobile, truck, and friction material manufacturers responded with written comments to the Federal Register announcement of the proposed EPA action. While most of the automobile and truck manufacturers were optimistic about the future availability of asbestos-free materials, they were unanimous in their opposition to a proposed phase-down schedule in which the amount of allowable asbestos would be phased out over a 10-year period. Instead, they favored a 5-year lead time prior to any ban. In addition, they were unanimously opposed to banning asbestos-containing materials for older aftermarket vehicles. Although suitable substitutes have been found for automobile front disc brakes, material qualification for rear automobile drum brakes and medium truck drum brakes is still in progress.

Friction product manufacturers gave mixed response to the issues. One manufacturer indicated that for many applications, suitable substitutes are available, although for many vehicle applications no qualified materials exist. Another manufacturer indicated that suitable substitutes were produced by their company, although no FMVSS 105 or FMVSS 121 qualification capabilities existed at their facility.

Recommended Future Work

Industry trends for the next 5 years appear to be directed toward the elimination of asbestos in all new vehicles. For these applications, the use of qualified non-asbestos friction materials may not present a vehicle safety problem over the life of the friction product. However, the use of unqualified non-asbestos materials for the aftermarket still remains a safety issue. If the eventual elimination of all asbestos in friction products is to be accomplished, additional future studies are required. Several possible research tasks are briefly outlined in the following sections.

Task 1: Determine Populations of Aftermarket Vehicle Classes and Brake System Designs in the United States

The purpose of this task would be to determine and project, over the next 10 years, the general classes of brake designs found on older vehicles (passenger cars and light trucks, medium trucks, and heavy trucks) that will require aftermarket friction materials. For example, it would be useful to determine how many passenger cars in the 3000-3500 lb weight range are fitted with duo-servo drum brake and how many utilize leading-trailing drum brakes. In addition, the population of vehicles having 4-wheel drum-brakes as opposed to rear wheel drum-front wheel disc brakes could be determined. Thus, vehicle populations would be assessed with respect to weight range, brake design, and front-to-rear braking balance.

This information would help the EPA to determine where the qualification of non-asbestos friction materials for the aftermarket would have the greatest impact on asbestos elimination. For example, if the results indicate that 80 percent of the passenger vehicles using asbestos materials are fitted with duo-servo rear drum brakes and front disc brakes, and are within the 3300-3800 lbs weight range, then the requalification of non-asbestos materials for these vehicles would have the greatest impact on asbestos elimination.

Task 2. Conduct Dynamometer and Vehicle Qualification Tests on Non-Asbestos Materials Using Representative Vehicles

The purpose of this task would be to determine whether current non-asbestos materials could be safely used in aftermarket vehicles designed for use with asbestos friction products. This task would draw upon the results of Task 1 by limiting the vehicle studies to these vehicles known to represent the majority of vehicles now in service. In this way, the study could be conducted in a more cost-effective manner.

This experimental study would use dynamometer and vehicle tests to determine friction product effectiveness under vehicle service conditions. The ability of brake systems and friction materials to satisfy Federal motor vehicle safety standards would also be assessed.

This second task would determine (1) whether safe effective substitute materials are available for some aftermarket applications and (2) what range of effectiveness currently exists among suppliers of aftermarket non-asbestos materials.

1. INTRODUCTION

The Environmental Protection Agency, under the authority granted by the Toxic Substance Control Act (TSCA), has proposed a ban on the production and importation of asbestos and asbestos-containing products. According to documents published in the Federal Register (Vol. 51, No. 19, Wednesday, January 29, 1986) the EPA has proposed several alternative approaches to eventually eliminate or drastically reduce the amount of asbestos used in the United States. The proposed actions apply to products containing asbestos, as well as raw asbestos mined or imported for incorporation into products.

The proposed ban on asbestos would have a direct effect on friction materials used in automotive, truck, transit bus and train brake systems. At the present time, many friction products contain asbestos. Asbestos provides several performance attributes for the brake lining both during its intended use as well as during its manufacture and assembly. Removal of asbestos from these materials raises the following questions:

(1) **Will asbestos-free friction products allow motor vehicles to meet current and proposed braking standards?**

Non-asbestos friction materials have added new complexities to brake system design and development because of their new, different, and sometimes unexpected functional properties. Furthermore, brake system development work becomes more difficult with the present shortage of fully evaluated, documented non-asbestos brake lining formulations. However, fully non-asbestos formulations for passenger cars, light trucks, and heavy trucks have been produced and more have been released for production. There is considerable controversy whether acceptable asbestos-free substitute friction materials have been found for some vehicle brakes, in particular some of the larger passenger car/medium truck drum brakes.

(2) Will the use of asbestos-free materials require redesign of braking components, such as actuation cylinders, distribution valves, and reservoirs and accumulators, to permit safe use of non-asbestos brake linings?

This question arises due to the proposed requirement for applying asbestos-free friction materials to existing vehicles that have braking systems designed for use with asbestos-containing friction materials. When non-asbestos friction materials are installed in existing vehicle systems with no alteration of the rest of the braking system, stopping distances may increase, required brake actuation forces may increase, resistance to fade may decrease, and undesirable brake stability problems may arise.

It would appear to be prohibitively expensive to replace brake system components to accommodate friction materials with different frictional characteristics because of the extensive redesign and retesting required. To assess the impact of the proposed ban, the feasibility will have to be addressed for the direct replacement of asbestos brake linings on existing vehicles with non-asbestos friction materials.

(3) What schedule for asbestos phase-out can be implemented without compromising vehicle braking performance and safety?

This question arises due to the possibility that in some applications acceptable substitute materials may not be available because of performance, manufacturability, or profitability issues. For some specialized vehicles, the market for friction products may be so small as to restrict the profitability of developing and manufacturing suitable asbestos-free friction materials and required associated hardware.

Objectives of this study were to:

(1) Define the technological issues associated with the EPA's

plan to disallow the use of asbestos in automobile and truck braking systems. Such issues would include:

- Identification of substitute brakes and systems,
- Influence of the ban on motor vehicle safety standards,
- Problems associated with replacing asbestos brakes on existing vehicles with alternative materials, and
- Pace of research and commercialization as they affect the proposed time for phase-out of asbestos.

(2) Collect relevant technical information required to resolve those issues.

(3) Present the findings and conclusions of the study regarding those issues where the state of existing knowledge is sufficient to make a sound engineering judgement.

(4) Define the limits of current knowledge and identify priority research topics where available information is not sufficient to draw firm conclusions.

This report addresses these and other issues created by the proposed EPA action against asbestos. Section 2 of the report describes vehicle braking systems now in use in both on-highway and off-highway vehicles. Table 1 lists the general vehicle classifications using these braking systems and vehicle examples affected by the ban. Section 3 of the report describes how friction materials are evaluated and qualified for vehicle use under Federal Motor Vehicle Standards and Society of Automotive Engineers (SAE) practices. Section 4 describes the performance of the various friction products. Section 5 covers vehicle applications affected by the proposed ban. Finally, Section 6 outlines the responses of the various industries to the EPA's proposed ban.

TABLE 1. MOTOR VEHICLES AFFECTED BY PROPOSED BAN

Vehicle Category	Example	Representative Brake Systems
On highway (low weight)	• Automobiles and light trucks	• 4 wheel drum • Rear wheel drum and front wheel disc • 4 wheel disc
On highway (high weight)	• Heavy trucks • Tractor-trailer combinations • Buses • Concrete mixers • Tank trucks	• Hydraulic drum • S-cam air drum • Wedge air drum • Air disc
Off highway	• Logging trucks • Mining trucks • Agricultural equipment	• S-cam air drum • Air disc • Wet (oil) disc

2. REVIEW OF VEHICLE BRAKING SYSTEMS

2.1 Section Summary

A review of vehicle braking systems is presented in this section and includes discussions of the performance requirements, factors influencing performance, and general design characteristics of the main braking systems. The main purpose of this section is to examine how vehicle braking performance is affected by the friction characteristics of both pad and lining materials. This is of particular importance in the aftermarket in which asbestos materials may be replaced with non-asbestos materials having different frictional properties. The main points of the section are:

- Vehicle brakes must provide consistent and dependable performance over a wide range of environmental and operating conditions, causing complex design and development challenges and necessitating performance tradeoffs.
- Brake lining friction and wear characteristics, along with thermal and mechanical properties, all affect the brake torque output, especially with high-servo-factor drum brakes. The performance of these brake systems, which are common on many American-made automobiles, is especially sensitive to the frictional properties of the brake lining material.
- Vehicle controllability and stability during braking is dependent upon the stability and consistency of the brake system. For example, an alteration in the front-to-rear braking balance due to a change in either the front or rear friction material may decrease vehicle controllability. The use of friction materials having different wear, stiffness, friction, or thermal expansion characteristics may cause a degradation in braking performance.
- Structural and vibrational behavior of brake assemblies can be significantly affected by the frictional, elastic, and structural properties of the friction materials. Brake squeal occurs when the brake and associated structural components are excited to vibrate due to friction. Some friction materials naturally damp or dissipate the vibration, while other mate-

rials accentuate vibration. The tendency for squeal is determined mainly through vehicle testing because prediction by analytical means is difficult.

2.2 Braking Performance Requirements

The primary requirement of a vehicle braking system is to provide the capability to decelerate the vehicle in a controlled manner at an acceptably high rate over the full range of in-service operating and environmental conditions. The brake system must provide consistent and dependable frictional behavior for all reasonable conditions. These conditions include:

- Environmental Conditions
  - temperature
  - humidity
  - road conditions (debris, wet, oily, etc.)
  - barometric pressure
  - contamination level
- Operating conditions
  - vehicle speed
  - vehicle trajectory
  - tire condition
  - brake system component condition
  - brake component temperatures
  - brake prior usage history
  - road condition and grade
  - traffic pattern

A conceptual schematic of a braking system is provided in Figure 1. The figure illustrates the feedback control nature of a braking operation, in which the driver is a critical controlling element. The driver must process information about this operating environment, based upon which he must respond by depressing the foot pedal with a degree of effort that he believes will decelerate the vehicle as he desires. The actual braking performance of the vehicle depends upon several factors, the more important of which are:

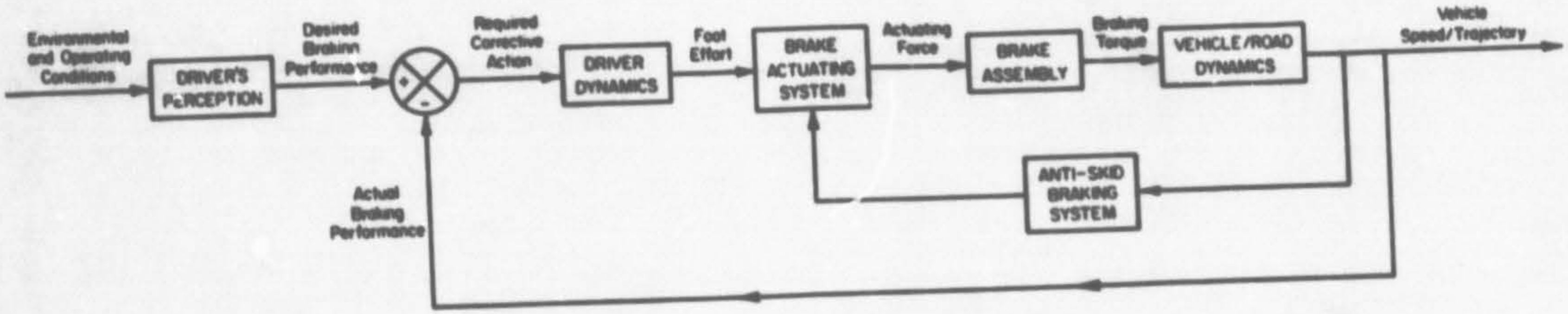


FIGURE 1. SCHEMATIC OF GENERALIZED BRAKING SYSTEM

- Accuracy of the driver's perception of the operating environment,
- Dynamic response characteristics of the driver,
- Predictability and reliability of the total brake system,
- Vehicle/road characteristics, and
- Response characteristics of the braking system.

In order to stop a vehicle safely, the brake system should provide repeatable, uniform deceleration for the same brake pedal input and provide braking force in proportion to pedal force. Further, vehicle path direction should be readily controllable by the driver during braking.

The limitation to decelerate a vehicle depends ultimately on road/tire traction, which varies with wheel slip. Maximum braking requires the brake torque to be just enough so that the resulting wheel-slip generates peak traction force available at the tire-road interface. Excessive brake torque causes a progressive increase in wheel slip and decrease in adhesion, resulting in wheel lockup and skidding. Skidding may produce an unsafe condition because directional control of the vehicle is reduced substantially and stopping distances may be increased. Rear-wheel lock-up during braking results in severe vehicle uncontrollability. For this reason, current European braking standards and proposed American braking standards require that in the event of wheel lock-up, the front wheels must lock before the rear wheels. To ensure this condition throughout the life of the friction material, both front and rear brake system performance must not be altered by friction material wear or by other changes in the material friction characteristics. Changes in the friction material properties, either due to replacing the brake shoes with different friction materials, or due to wear, prior operating history, temperature, and load effects, will change the response characteristics of the braking system.

2.3 Influence of Brake Friction Material Characteristics on Brake System Response

There are several scenarios in which an existing hydraulic or pneumatic system would require modification or redesign to accommodate changes in the properties of the brake friction material. These are summarized in Table 2. As indicated in the table, substitution of non-asbestos friction materials for original asbestos linings requires characterization of the substitute material properties, followed by an evaluation or verification of the performance of the existing brake system with the non-asbestos materials. Due to brake system design differences, this must be done on a model-by-model basis.

For new vehicles, non-asbestos friction materials may be incorporated into a new brake system design. Depending on the characteristics of the non-asbestos friction materials, compared with those of the asbestos materials, the new brake system design could involve minor modifications of existing designs or completely new brake components.

In order to achieve adequate braking performance, brakes are designed primarily on the basis of wear, stability, brake or shoe factor, (ratio of brake torque to applied force) and pedal travel.(1) These parameters are interrelated. For example, lining material thermal expansion may require added running clearances to avoid parasitic drag. This then results in the need for greater brake pedal travel, which may lead to a master cylinder resizing. If pedal forces then become too great, a booster may need to be added or increased in size. Some of these relations are discussed in the following sections.

2.4. Influence of Brake Design on Brake Effectiveness

As mentioned previously, it is important that a vehicle have the ability to be decelerated rapidly and controllably during emergency braking. Thus the response of the vehicle to the driver's brake "commands" must be predictable, repeatable, and fast enough to stop the vehicle in a short distance, but slow enough that the driver can respond effectively with subsequent corrective braking and steering commands, e.g., to avoid skidding or "fishtailing".

The relationships between braking (frictional) torque, applied force, and the coefficients of friction have a strong influence on vehicle stability. The parameter that most strongly affects the stability of brakes is the shoe or brake factor (also called effectiveness). The brake effectiveness is defined as the ratio of the brake friction torque to the applied force and is used commonly to describe the performance of brakes.

TABLE 2. INFLUENCE OF SOME BRAKE LINING PROPERTY CHANGES ON BRAKE SYSTEM RESPONSE WITH DESIGN MODIFICATIONS TO COMPENSATE

	Change of Brake Lining Properties	Potential Response of Brake System	Needed Design Modifications
Friction Properties	• Lower Friction Coefficients - Front brakes - Rear brakes - Both front/rear	• Greater Pedal Forces Required, Leading to: - Early rear skid - Early front skid - Low brake capacity	• Larger Booster or Small Master Cyl. - Big front w.c. - Big rear w.c. - System redesign
	• Higher Friction Coefficients - Front brakes - Rear brakes - Both front/rear	• Lower Brake Pedal Force Required, Leading to: - Early front skid - Early rear skid - "Touchy" pedal	• Smaller Booster/ Big Master Cyl. - Small front w.c. - Small rear w.c. - System redesign
	• Poor Fade Characteristics - Green fade - Thermal fade - Water fade - Flash fade	• High Brake Pedal Force Required For: - Initial hot brake - Any hot brake, - Wet brakes - High speed stops	• Recalibrate/Add Booster - Scorch linings - Modify linings - Shield brakes - Modify linings
	• Inconsistent Friction Level - Green linings - Usage history - Wear depth - Within batch - Batch-to-batch	• Varied Brake Pedal Forces Needed With: - New brake linings - Temperature change - Mileage driven - Brake imbalance - Car-car variations	• Change Linings/ Redesign Brake - Modify linings - Modify linings - Modify linings - Improve process - QC improvement
	• Environmental Sensitivity - Water/water vapor, - Road dust - Oily contaminants - Oxide/rust effects	• Brake Pedal Force Sensitive to: - Humidity - Dust pickup - Road rain splash - Moist storage	• Change Linings/ Redesign Brake - Modify linings - Shield brakes - Shield brakes - Materials change
Mechanical Properties	• Lower Compression Modulus	• Higher Brake Pedal Travel	• Redesign/Stiffen Actuation System
	• Higher Compression Modulus	• Noise and Uneven Effectiveness	• Reduce Shoe/Drum Stiffness
	• Higher Thermal Expansion/Growth	• Brake Dragging and Hot-Spotting	• Add Clearance or Thin Linings
	• Lower Tensile Strength	• Lining Fracture, Cast Iron Scoring	• Use More Rivets, Bond/Mold Linings
	• Lower Toughness	• Handling Breakage	• Alter Processes

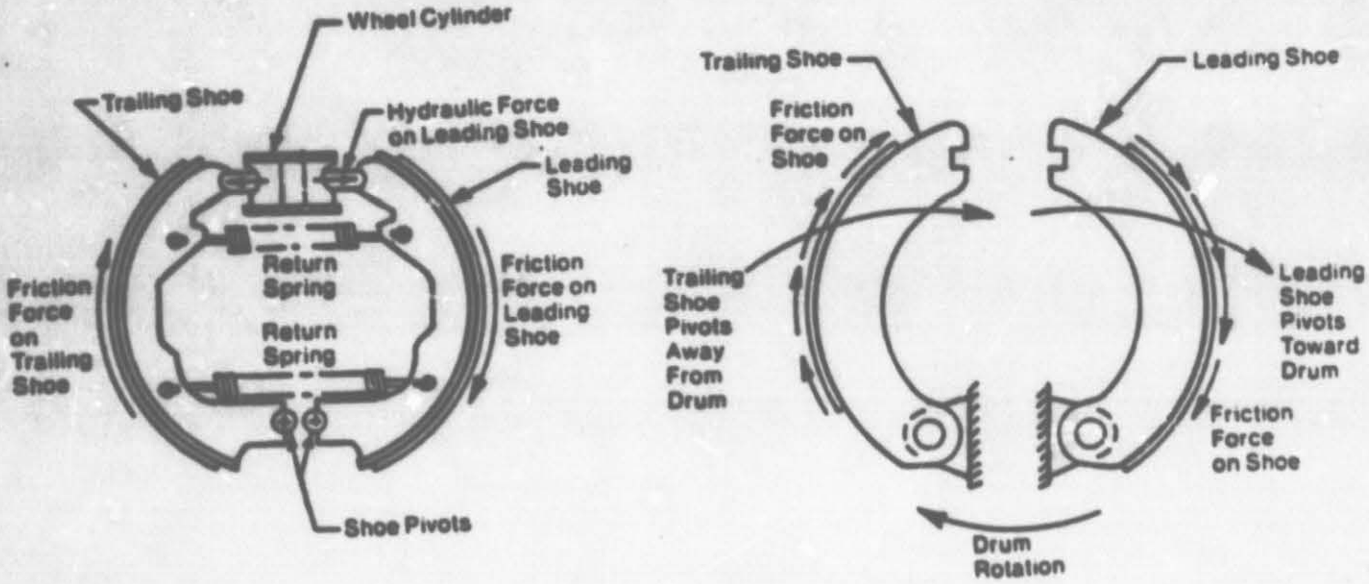
Figure 2a shows the forces acting in the shoes of a simple leading-trailing drum brake. As shown, the friction force on the leading shoe causes it to be further loaded against the drum, increasing its effectiveness, while the friction force on the trailing shoe causes it to oppose the application force, decreasing its effectiveness.

In the duo-servo design, Figure 2b, the friction force of the primary shoe is used to apply the secondary shoe, thereby markedly amplifying the application force. The increase in brake loading due to friction is referred to as self-actuation, and this phenomenon can be used to increase the brake effectiveness. This design has been and still is used extensively on American cars using asbestos-containing brake linings.

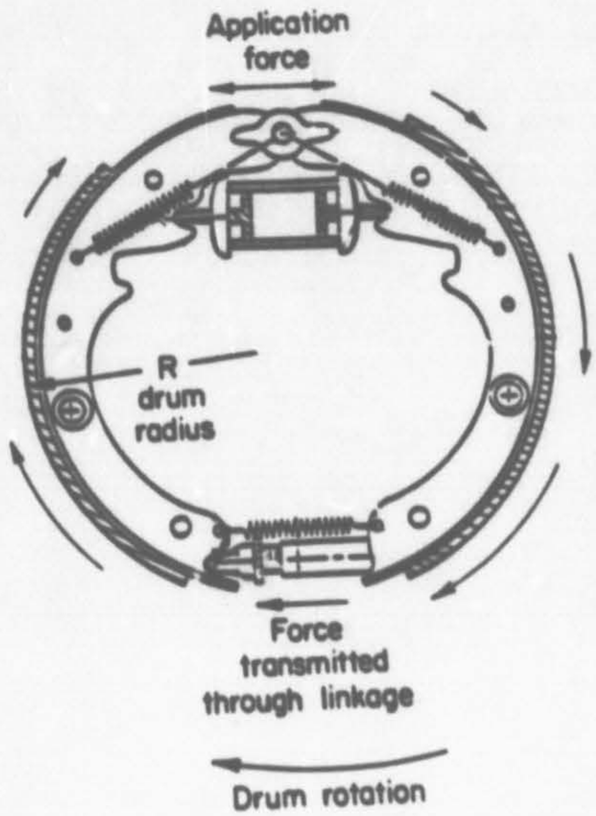
Although the phenomenon of self-actuation can increase brake effectiveness, the effectiveness is strongly influenced by the frictional properties of the lining material. Figure 3 shows the relationship between brake effectiveness and lining friction coefficients for different drum brake designs and for an automobile disc brake. Duo-servo drum brakes are widely used in American automobiles, while leading-leading systems are found on many transit buses and heavy trucks. Leading-trailing systems are also found on most heavy trucks and on many automobiles. Assuming a nominal friction coefficient of 0.4, a 12-percent change in friction coefficient can alter the brake effectiveness by approximately 44 percent for a duo-servo drum brake, 33 percent for the leading-trailing drum brake, and only 12 percent for a disc brake. Figure 3 also shows that for automobile rear drum brake systems, friction materials qualified for use with duo-servo systems may not perform satisfactorily when used with leading-trailing systems. Conversely, materials qualified for use in leading-trailing systems may precipitate rear wheel lock-up when used with a more effective duo-servo system.

Aftermarket friction materials from different manufacturers can exhibit a wide variance in friction characteristics. This can lead to variable and unpredictable brake performance, even with materials containing asbestos. Under current law, aftermarket friction materials do not have to meet Federal Motor Vehicle Safety Standards.

As more major OEM friction material suppliers phase out asbestos materials, the burden of supplying materials for the aftermarket will fall on these secondary aftermarket suppliers. Under the proposed ban on

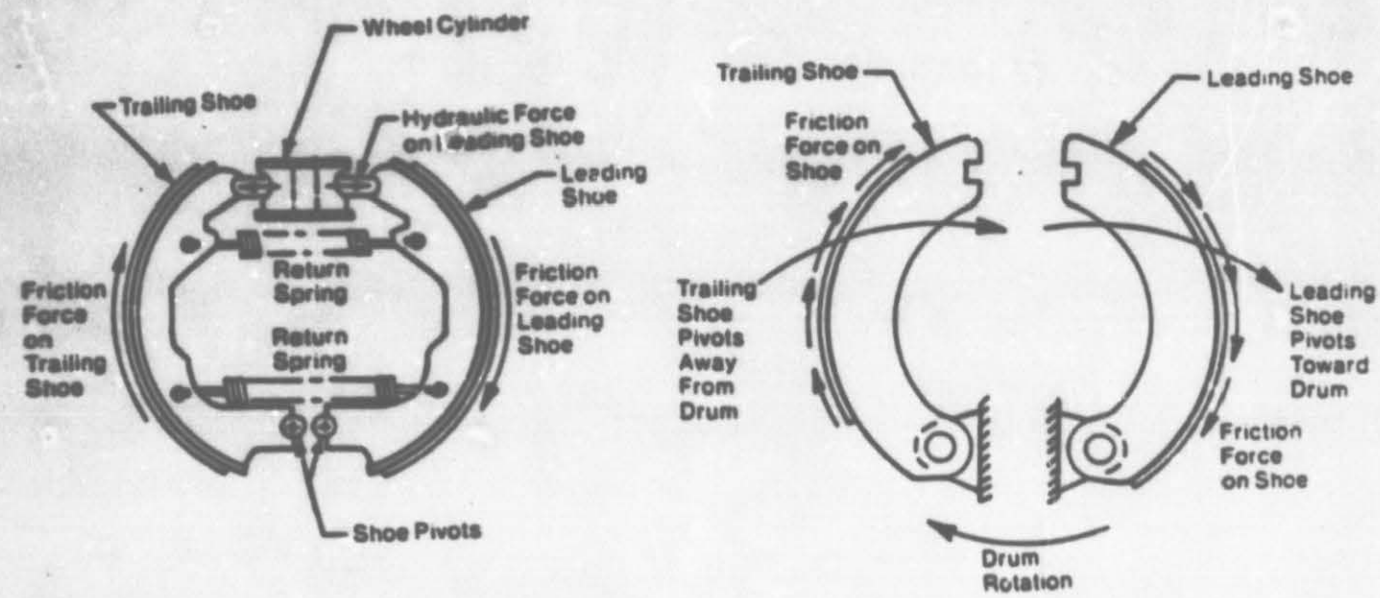


a. leading-trailing

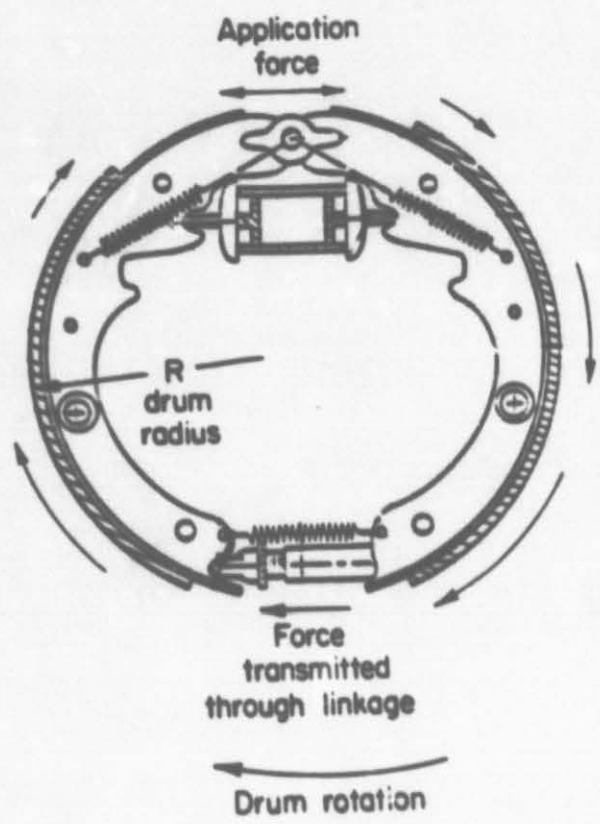


b. duo-servo

FIGURE 2. FORCES ACTING ON BRAKE SHOES OF TWO COMMON DESIGNS



a. leading-trailing



b. duo-servo

FIGURE 2. FORCES ACTING ON BRAKE SHOES OF TWO COMMON DESIGNS

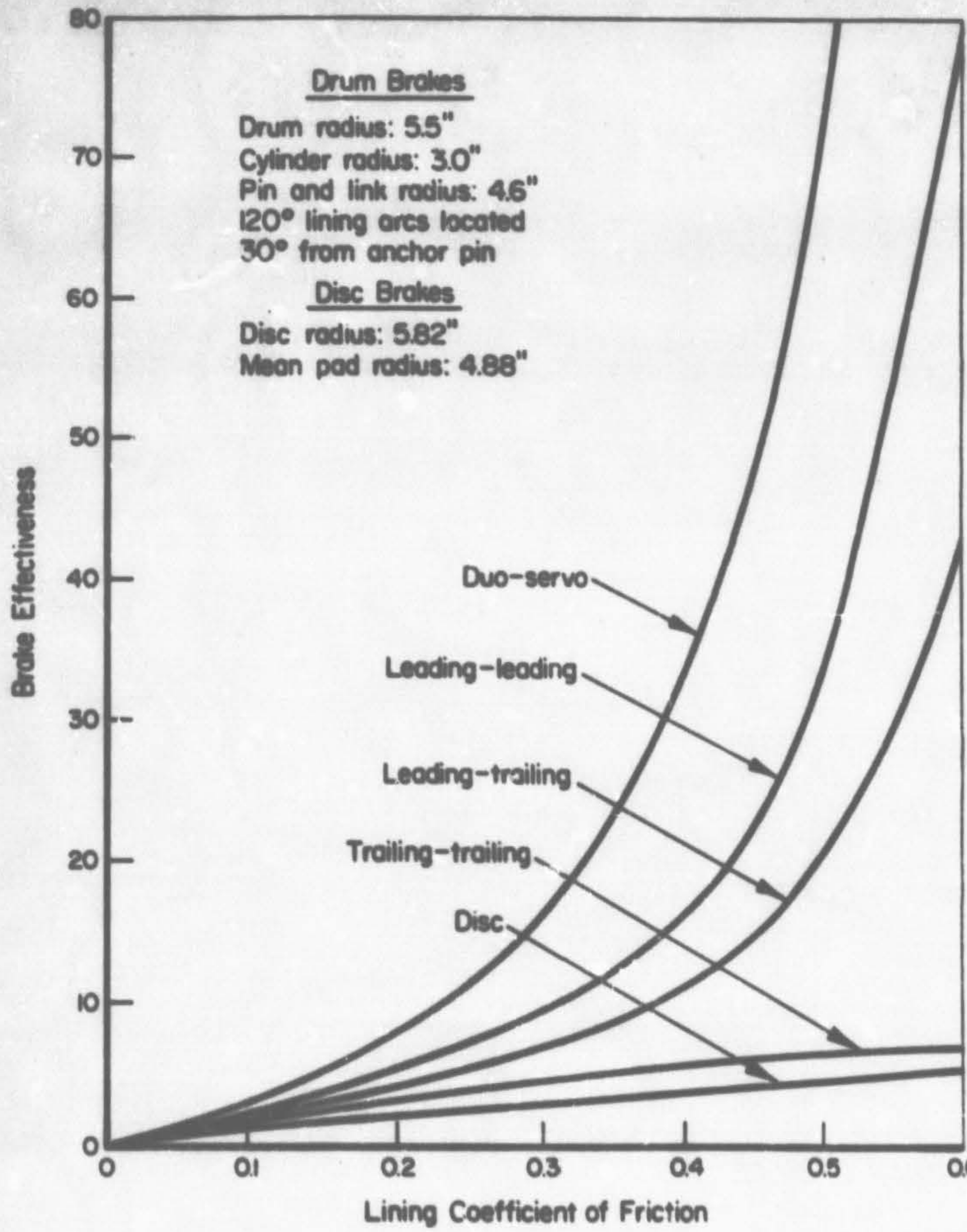


FIGURE 3. RELATIONSHIP BETWEEN BR^KE EFFECTIVENESS AND BRAKE DESIGN FOR VARIOUS LINING FRICTION LEVELS

asbestos-based linings, the brake system engineer would have two choices. First, the drum brake could be redesigned and redeveloped for acceptable performance with non-asbestos linings. Second, the designer could wait for a lining formulation to be developed that can be used directly in existing drum brake designs. This is a critical decision. Redesign of a brake assembly is costly, time consuming, and probably unrealistic. However, waiting for the development of a suitable universal non-asbestos replacement friction material--that has yet to be made--involves the risk of not having acceptable aftermarket components if asbestos-based brake linings are banned.

2.5 Influence of Brake Lining-Brake Drum Pressure Distribution on Brake Effectiveness

For drum brakes of the same design, the use of different materials exhibiting similar friction coefficients is not sufficient to ensure consistent and even braking throughout the life of the material. The use of a material that exhibits different wear or thermal properties can be sufficient to change the effectiveness of the brake system. Figure 4 shows the variation in effectiveness for the same brake design but for different brake lining pressure distributions. Note that large changes of brake effectiveness are possible for the same value of friction coefficient due to the effect of lining pressure distribution.

Several factors can lead to uneven and inconsistent brake lining-brake drum pressure distribution, but the most significant are wear and thermal distortion. Wear tends to shift the center of pressure location. Thus, substitute friction materials with different wear rates from the original asbestos materials may also influence stability by changing the center of pressure. A reduction in brake effectiveness, or an increase in brake effectiveness leading to wheel lock-up, could be possible consequences of improper friction material selection.

The profiles of the brake linings also are affected by thermal distortion. Brake lining expansion through the friction material thickness is often much greater for non-asbestos brake linings, and these friction materials also tend to be much stiffer. Therefore, the contact geometry and pressure distributions will be different, which can affect the friction

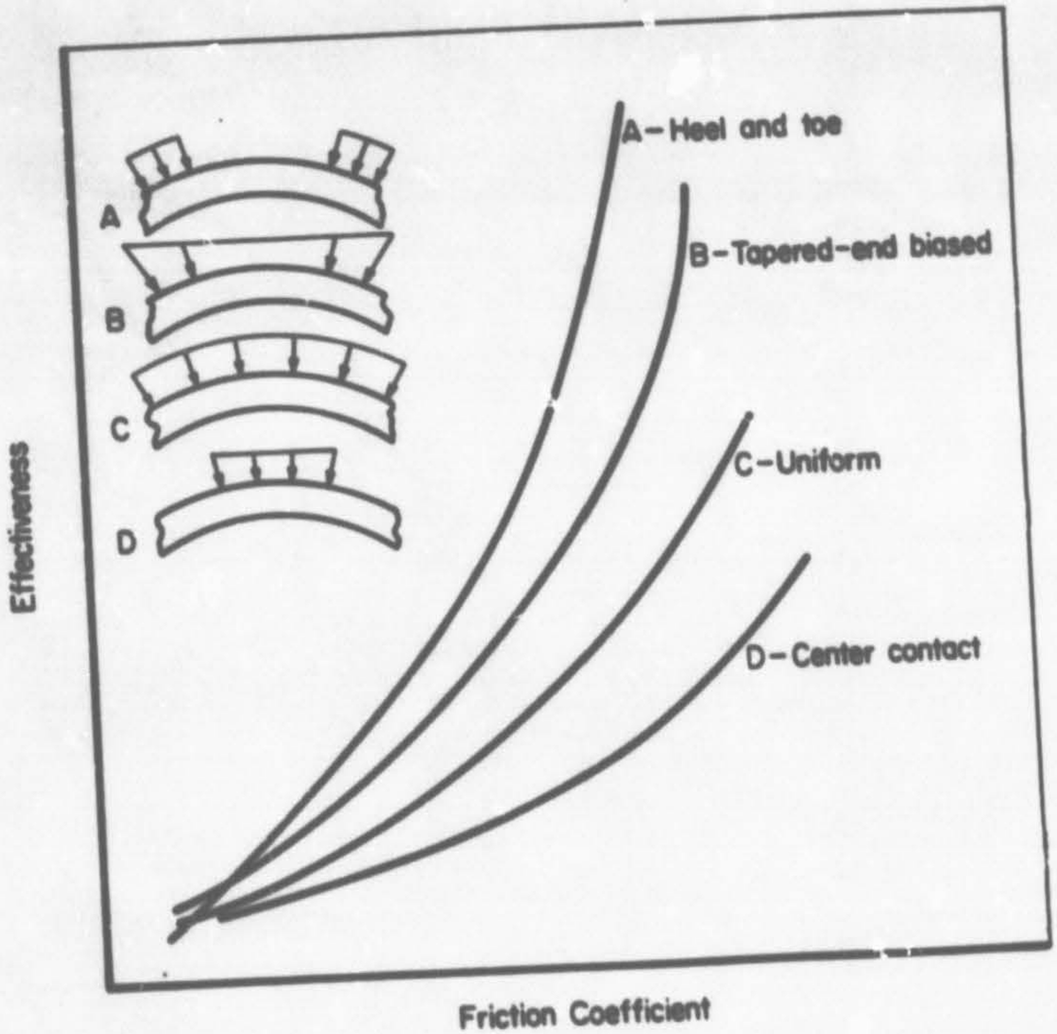


FIGURE 4. EFFECT OF LINING PRESSURE DISTRIBUTION ON BRAKE EFFECTIVENESS FOR A LEADING SHOE DRUM BRAKE

forces generated at the contact area, especially on the larger drum brake assemblies. For this reason, friction materials with higher thermal expansion rates may cause inconsistent braking performance, especially with varying brake temperatures.

An added complication results from the greater thermal expansion rate and compression stiffness of many non-asbestos friction materials. This is called hot-spotting, a thermoelastic instability that causes the lining pressure distributions to become localized, with resultant high thermal stresses and erratic friction values. The basic principles are simple, but the total system effects can be extremely complex.

For example, one particular brake lining location may have a greater clamping load than average, providing greater friction and heat generation. This causes that location to expand, further increasing its excess load. If the lining wear rate is low, this cycle can continue for some time, leading to the formation of a hot spot. Hot spotting tends to occur during low temperature brake usage, with light brake applications, and during braking from highway speeds. Since this brake usage is not severe, it can inadvertently be overlooked in the early stages of the brake development process.

2.6 Issues of Friction-Induced Vibration and Brake Noise

Vehicle braking systems generally include several structural components, e.g., calipers, pedal linkages, etc. Forces generated during braking can cause high stresses in these brake components and in vehicle-associated components, e.g., axles and suspension elements. These stresses result from the nominal braking torque as well as from thermal and other dynamic loads. Sufficiently large dynamic and thermal stresses superimposed on the nominal braking stresses might promote fractures or fatigue failures in some vehicle structures, which then could result in an unsafe operating conditions. The brake friction material properties strongly influence the dynamic behavior of the vehicle structure during braking because these properties determine the magnitude and frequency of the braking torques generated at the friction interface. For example, phenomena such as brake squeal, chatter, and groan produce structural vibrations of vehicle components which may be either reduced or increased by substituting different brake friction materials. The influence of a particular braking material on structural vibrations depends strongly upon the specific brake system design. Therefore, replacement materials should be evaluated carefully for critical vehicle applications.

Another structural consideration occurs in attaching the friction material to the brake shoe. This can be done by riveting, bonding, or integrally molding the lining to the brake shoe. Non-asbestos linings generally are stiffer, more brittle, and more highly anisotropic, i.e., their properties are sensitive to orientation, which can provide attachment challenges.

Friction-induced vibration and noise can occur under some conditions with vehicle braking systems. The phenomenon has received considerable attention, and attempts are normally made to quantify the parameters that influence its initiation. In the final analysis, however, this phenomenon is usually evaluated experimentally on a model-by-model basis.

Although the principle of sliding friction is extremely complicated and not totally understood at the present time, it is known that friction is not a steady-state process. Vibration occurs because of this variation in friction force in the related components. It is also known that friction-induced vibration occurs via several different yet distinct mechanisms. It is possible to have more than one vibration-exciting mechanism active at a given time. This makes brake vibration corrections complex. Some non-asbestos friction materials tend to be more prone to generate friction excited oscillations, for as yet uncertain reasons. It is felt that their generally greater energy storage modulus (stiffness) and lower energy loss modulus (dampening) are probable sources of greater tendencies for vibration and noise. Asbestos is much like many strands of rope in a brake lining formulation, although much finer in size. This is believed to provide the greater inherent dampening of asbestos friction materials. Fiberglass, aramid fiber (Kevlar), steel wool, wolastonite, and other non-asbestos reinforcing fibers typically are found as single solid elements, contributing minimally to the lining damping factor.

To clarify some of the mechanisms of friction-induced vibration, the following sections discuss these mechanisms in more detail.

2.6.1 Stick-Slip

At low brake application speeds, it is possible for the brake lining and drum or disc to stick together for a short time, twisting up the vehicle suspension assembly. When the restoring torque builds up to the static breakaway value, the lining again slips against the drum/disc. This stick and slip cycle repeats rapidly, generating brake chatter, groan, or squeal vibration. This mechanism is attributed to a difference in the static and kinetic frictional torques and the spring-like restoring forces acting on brake components. The stick-slip mechanism produces a self-excited vibration with displacement-versus-time characteristics similar to a saw-shape form. This is the usual mechanism for low-speed brake chatter, although it can also exist in the form of a higher frequency squeal.

2.6.2 Negative Slope of the Friction Velocity Curve

This vibration inducing mechanism arises from a negative slope of the friction-versus-sliding velocity curve characteristic of certain materials in specific speed ranges. This causes instability in the system and excites vibrating components into nearly sinusoidal waveforms. An explanation is based on observations that the brake drum or rotor surface roughness asperities require a finite amount of time to produce equilibrium deformation of the brake lining material. The time that is available to deform the lining is decreased with increasing speed, restricting the time to compress the asperities in the friction material. Thermal effects, such as interfacial softening and changes of the chemical composition of surface layers, also have been offered as an explanation for the cause of the negative slope of friction versus velocity.

2.7 Comparison of 4-Wheel Disc Brake Systems With Front Wheel Disc-Rear Wheel Drum System

The almost standard use of front wheel disc brakes for automobiles has been due to some performance characteristics provided by this design. Because these brakes and the friction materials used with them (notably semi-metallics) can operate at higher temperatures than drum brakes, the vehicle's braking balance can be shifted toward the front, reducing the likelihood of rear wheel lock-up during severe braking conditions. In addition, since automobile front brakes are exposed to water, disc brakes provide for more effective wet braking under many road conditions.

Many European automobiles imported to the United States have been fitted with 4-wheel disc brakes. There appears to be three reasons for implementing these brake systems. First, the effectiveness of disc brakes is less affected by friction material performance than the effectiveness of drum brakes. Since European safety standards require front brake biasing to prevent rear wheel lock-up, this situation is more readily ensured by using similar brakes on all four wheels and adjusting the front-rear pressure proportioning valve accordingly. Front brake biasing can be accomplished with vehicles outfitted with rear drum brakes, but the drum brakes require friction materials that exhibit very stable friction performance in order to ensure consistent performance (Figure 3). Second, in the absence of suitable non-asbestos linings, some European manufacturers elected to use proven semi-metallic materials and disc brakes as a means of eliminating asbestos. Third, in the United States, there is a perceived performance advantage provided by the term "4-wheel disc brakes", and so such systems are usually provided on higher priced imports. More inexpensive automobiles produced for wide-spread consumption in Europe (Fiat, VW, Renault, etc.) are still equipped with rear wheel drum brakes.

Rear wheel disc brakes have disadvantages. Currently used materials, semi-metallics, exhibit poor friction performance at low temperatures and optimum performance at high temperatures. The effectiveness of the parking brake can be adversely affected, since these brakes are usually applied when the brakes are hot and then required to hold as the brakes cool down. Also, the pad-disc normal load for the parking brakes can decrease as the pads cool down and contract from their hot, expanded geometry. The rear disc braking surfaces also are more prone to contamination by mud and road debris thrown from the front wheels.

3. EVALUATION OF FRICTION MATERIAL PERFORMANCE

3.1 Section Summary

The performance of friction materials, as applied to automotive brake systems, is reviewed in this section along with the pertinent friction material testing devices and relevant testing procedures and standards. Main points presented are:

- Friction materials are expected to perform satisfactorily over a wide range of operating and environmental conditions as an important element of the total brake system.
- Many critical performance considerations, such as fade and fade recovery, are sensitive both to the friction material and to the brake system in which it is tested. Therefore, full-system testing is required for proper evaluation.
- Friction stability can vary with both thermal and mechanical history. Therefore, short-term evaluations and those with narrow ranges of brake temperatures can produce incomplete data leading to erroneous conclusions on brake compatibility and performance.
- Laboratory specimen test machines, such as FAST and FMTM, may be appropriate for quality control tests and material screening, but they are not able to determine the acceptability of substitute friction materials or to compare different friction materials.
- Full brake inertial dynamometers, properly instrumented and utilized, can be used to screen friction materials and determine some component performance behavior. Typically, these large and expensive devices do not adequately simulate the airflow over the brake and the environmental conditions of vehicle service.
- Good brakes are those with few minor faults. Brake development testing therefore is time consuming and costly, since a wide range of conditions must be evaluated in the process of brake development.

- Federal Motor Vehicle Safety Standards (FMVSS 105, 121, and the proposed 135) are severe-usage brake tests which are only one of many standards that new (OEM) vehicle brake systems must meet. No standards need be met by aftermarket friction materials.

3.2 General Evaluation Criteria

Friction material performance for vehicle brake systems may be qualified by meeting the requirements of the Federal Safety Standards, Society of Automotive Engineers (SAE) recommended practices, along with brake component and vehicle manufacturers' standards. These experiments are directed to maximize safety, dependability, and customer satisfaction over a variety of brake operating conditions. For new vehicles, compliance with federal and state motor vehicle safety standards is only the starting point for acceptance of a brake system.

This section of the report discusses the criteria and techniques used to determine friction material suitability and performance. Full evaluation of a friction material requires installation into a complete brake system. It is only in the full brake system that many of the important brake lining attributes such as fade, fade recovery, environmental effects, and varying service factors may be properly determined.

Vehicle brakes are required to operate under a wide range of conditions, from steep downhill grades with a heavily loaded vehicle to minimal loads on interstate highways. Vehicle brakes must be completely reliable and must be minimally affected by temperature, water, or contamination. Brake actuation forces should be properly distributed, and brake friction must be consistent throughout the life of the friction material. Pedal actuation forces should not exceed the capabilities of a wide range of drivers.

Vehicle braking performance can be closely related to loss of directional control in vehicles. Under skidding conditions, the tendency for wheel lockup in some brake systems can make controlling the vehicle more difficult. Commercial vehicles with lower brake effectiveness have been shown to be less likely to encounter loss of control in accidents, presumably due to lower usage speeds and reduced tendency for wheel lockup (2).

Variation in the front-to-rear brake balance, due to changes in frictional performance, may adversely affect safety through reduced directional control and stopping efficiency. The subject of vehicle brake systems is discussed in more detail in Section 2.

Section 3.2 of the report describes some of the more important friction material performance characteristics that are evaluated during original equipment manufacturer (OEM) brake system qualification experiments. These include: Fade Resistance, Fade Recovery, Delayed Fade, Effectiveness Versus Speed, Friction Stability, Wet Friction, Moisture Sensitivity, and Wear Rate. Each of these important performance characteristics will be highlighted in the following sections.

3.2.1 Fade Resistance

Brake fade refers to a loss of brake effectiveness, generally as the result of excessive brake temperatures. Such excessive temperatures may occur under hard brake usage conditions or under less stringent conditions, should component cooling be restricted. Brake fade may occur under particularly hazardous driving conditions, such as descending steep and winding mountain roads. Five types of brake fade have been described:

- Thermal--due to high brake system bulk temperatures,
- Delayed--due to resin migration during brake cooling,
- Blister--due to effects of near-surface lining blisters,
- Flash--due to high speed, high torque demand braking, and
- Water--due to partial lubrication from water contamination.

Figure 5 shows a performance comparison between a good friction material and a poor material. The poorer friction material exhibits a more rapid drop-off of brake effectiveness, compared with the better material. Since poor brake fade behavior could also be exhibited by high quality materials if used in inappropriate brake applications, brake lining fade behavior is meaningful primarily in the context of a particular brake lining, brake, and vehicle application. It should be noted that although these curves are continuous, the driver applies the brakes at discrete points along the curve. If the last application happens to be on the "knee" of a performance curve, then the next brake application will yield different and unexpected brake system response.

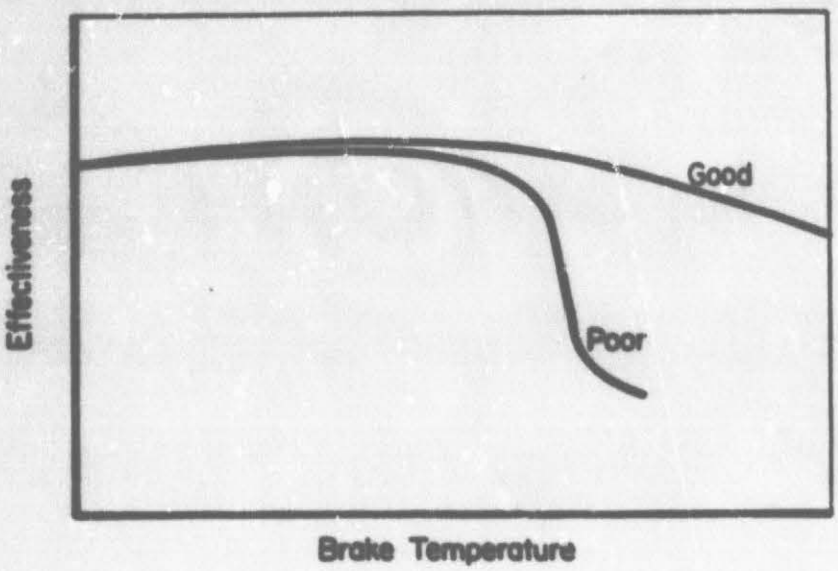


FIGURE 5. FADE CHARACTERISTICS OF GOOD AND POOR BRAKE FRICTION MATERIALS

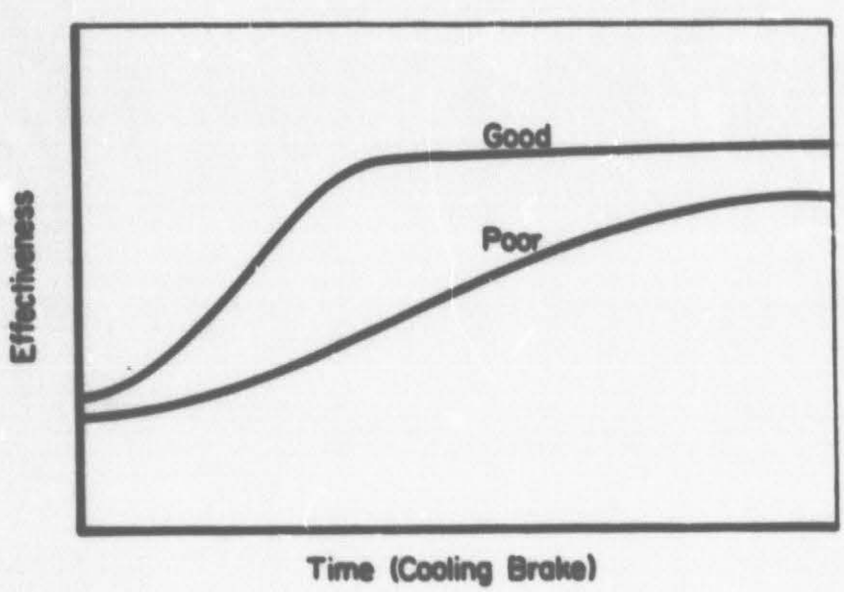


FIGURE 6. FADE RECOVERY CHARACTERISTICS OF GOOD AND POOR BRAKE FRICTION MATERIALS

3.2.2 Fade Recovery

Fade recovery refers to the ability of the friction material to quickly regain normal effectiveness after fade. This recovery is shown in Figure 6. As the brake cools with time after experiencing fade, the friction level should return rapidly to approximately the pre-fade level. Poor friction materials may exhibit slow recovery, compared with good friction materials, and may produce either a decrease or increase of brake effectiveness as a lasting consequence of the fade.

3.2.3 Delayed Fade

Delayed fade is a phenomenon which may occur with some friction materials. This phenomenon is illustrated in Figure 7. During fade recovery, brake effectiveness may drop unexpectedly, causing a temporary but potentially hazardous increase of required brake pedal force. This "delayed fade" is insidious in that it is often totally unexpected. It occurs well after a period of hard brake usage and usually with no warning signs.

3.2.4 Brake Effectiveness Versus Speed Characteristics

To ensure even braking over a wide range of stopping speeds, the brakes on each axle should exhibit similar effectiveness characteristics at all vehicle speeds. In general, brake effectiveness decreases with increasing speed. Consequently, a brake application from 60 mph usually requires greater brake pedal effort than from 20 mph. Good brake linings provide less speed spread, or difference in effectiveness at different braking speeds, and good brake systems employ friction materials that provide a proper balance of front-to-rear brake effectiveness at any speed. Figure 8 shows the general relationship between brake effectiveness and deceleration for brakes with poor and good "speed spread" performance. As illustrated, the effectiveness at 75 mph is markedly different from that at 25 mph for this brake, using a relatively poor friction material. Disc brakes are inherently less speed sensitive than high-servo-factor drum brakes, so they typically show less speed spread.

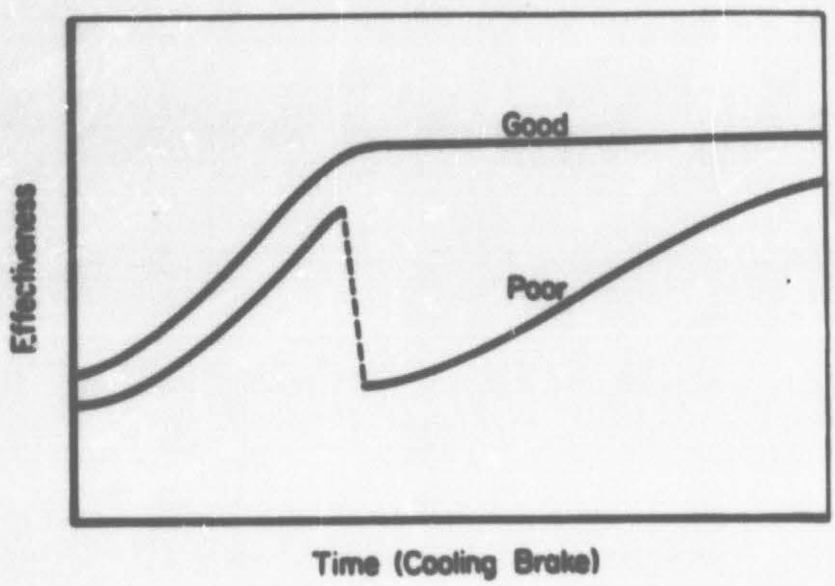


FIGURE 7. DELAYED FADE CHARACTERISTICS OF FRICTION MATERIALS

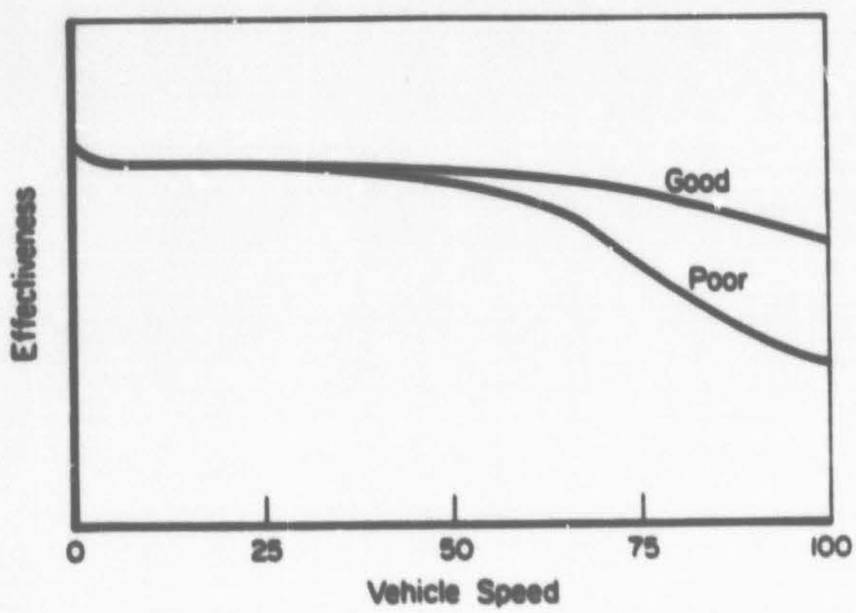


FIGURE 8. SPEED VERSUS BRAKING PERFORMANCE CHARACTERISTICS FOR GOOD AND POOR FRICTION MATERIALS

3.2.5 Friction Stability

To ensure consistent vehicle braking performance, the brake effectiveness characteristics should be stable throughout the life of the brake linings. Figure 9 shows the difference between a poor material and a good material in this regard. The brake effectiveness of poor friction materials can deteriorate with accumulated use history and wear, as indicated.

On vehicles equipped with a balanced set of friction materials on all four brakes, a gradual reduction in brake effectiveness may be marked only by a slight increase in pedal pressure to decelerate the vehicle, but brake stability will be essentially unaffected. However, on vehicles employing two unmatched friction materials on the front and rear axles, a shift in effectiveness of one braking axle relative to the other will alter braking balance and could adversely affect controllability of the vehicle during hard braking.

3.2.6 Wet Friction

The performance of vehicle brakes when wet is a significant safety concern. Disc brakes usually are less affected by water than are drum brakes largely because of the lower inherent servo factor in disc brakes. However, both disc and drum brakes can show large effectiveness losses when wet.

As expected, poor friction materials can provide a greater loss of effectiveness and take a considerably longer time to recover friction capability, when wetted, than experienced by good materials. This is shown in Figure 10. Permeability, heterogeneity, and compression stiffness are some of the brake lining properties which determine wet friction response. Complete understanding of this behavior is not known, so full brake dynamometer and vehicle tests are used to establish the wet friction behaviors of a brake system.

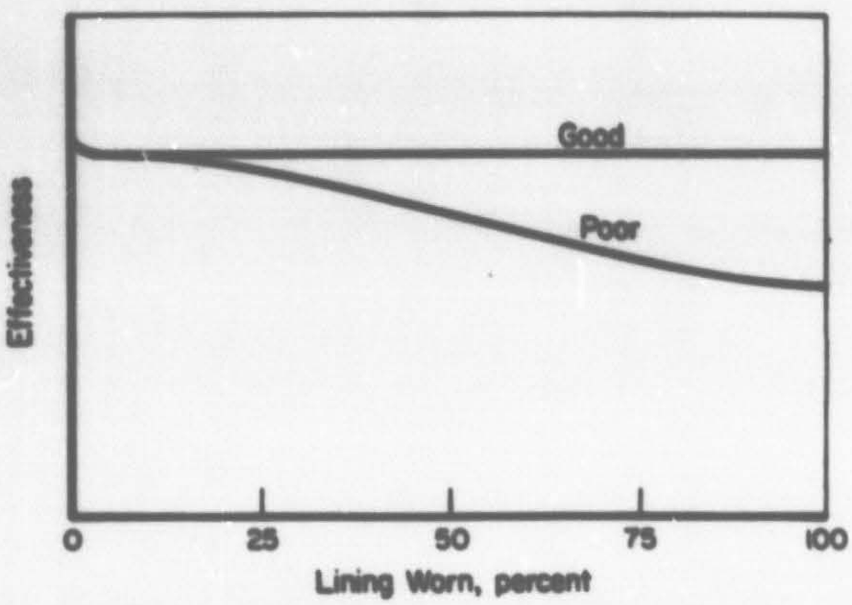


FIGURE 9. FRICTION STABILITY CHARACTERISTICS OF BOTH GOOD AND POOR FRICTION MATERIALS

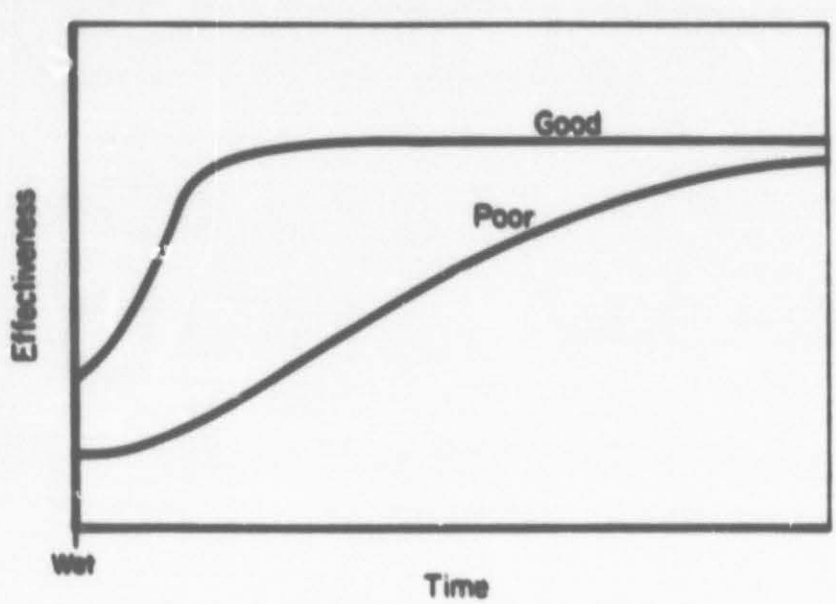


FIGURE 10. WET BRAKING PERFORMANCE FOR GOOD AND POOR PERFORMANCE BRAKING MATERIALS

3.2.7 Moisture Sensitivity

Friction materials are porous, fiber-reinforced composites that are capable of absorbing atmospheric moisture when a vehicle is parked, such as overnight. For some friction materials, this moisture has been shown to lower brake effectiveness temporarily, leading to a phenomenon called "morning sickness". Other morning sickness effects result from rusting of the cast iron disc/drum surface when a vehicle is parked for some time, causing abnormally high initial brake effectiveness. Under some conditions, it is possible for the friction material to become rust-bonded to the cast iron. Substantial driving torque may be required to break the interface free, and the rusted surface of the brake drum or disc may generate a temporarily uneven brake torque.

Figure 11 depicts the effect of moisture sensitivity on brake effectiveness. The ideal brake assembly exhibits little or no moisture sensitivity. When present, it usually persists for a few brake applications and disappears when brake heat drives the moisture from the brake lining or wear removes the surface rust.

3.2.8 Lining Wear Rate

Wear rates of friction materials depend upon temperature, prior use, speed, and load. In general, wear is directly proportional to applied normal load and speed. At moderate brake drum and disc temperatures, friction material wear rates are not affected greatly by temperature. However, at high brake temperatures, wear of the friction material may increase exponentially due to thermally induced degradation of the organic resin binder material[3].

Figure 12 shows representative wear performance for three different types of friction materials. Low quality materials may utilize an inferior binder resin (with poor heat resistance), providing a wear curve like that labelled "A". This may give acceptable wear rates at low brake temperatures, but rapid wear rates at higher brake temperatures. OEM type materials behave like curve "B", and heavy duty brake linings wear like curve "C". Note this heavy-duty lining does not improve wear life, except at the higher brake temperatures.

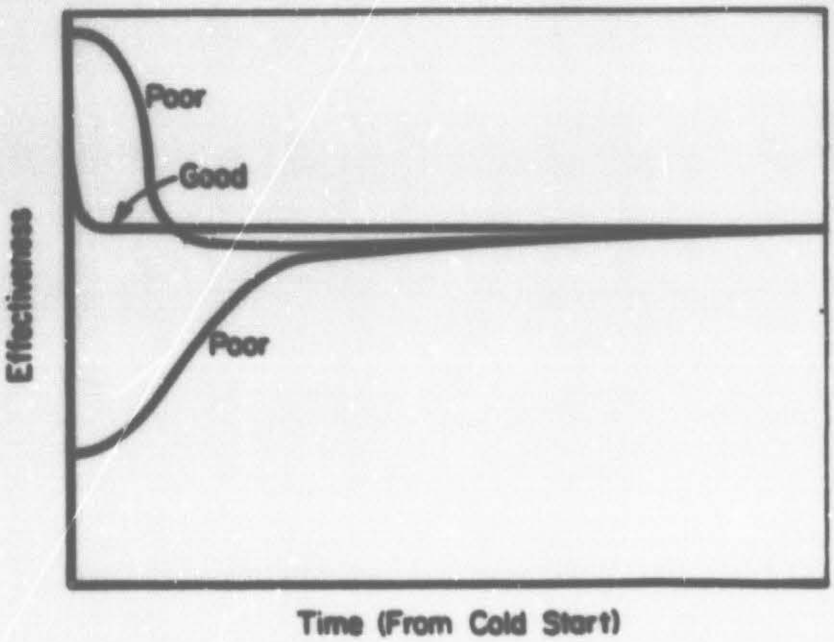


FIGURE 11. EFFECT OF MOISTURE SENSITIVITY ON BRAKING PERFORMANCE

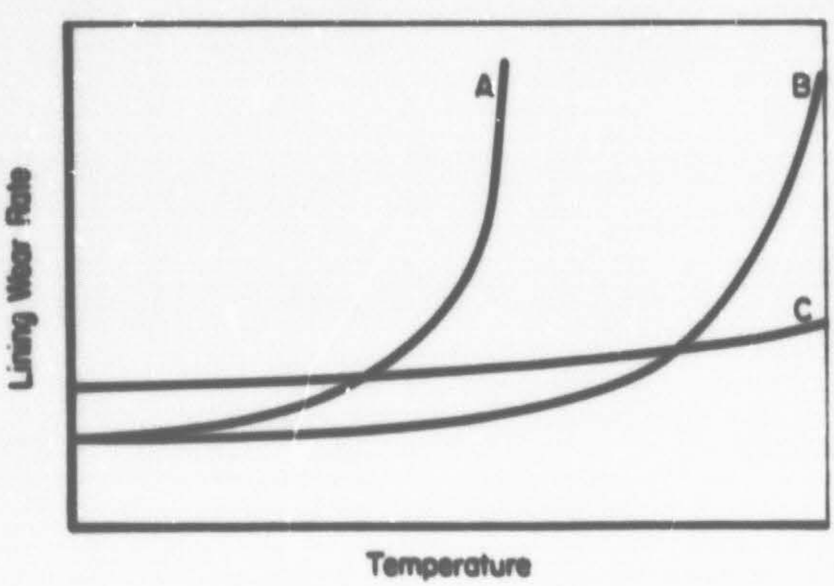


FIGURE 12. WEAR PERFORMANCE FOR BRAKING MATERIALS

Since the full brake assembly represents a tribological system, surface conditions at each contacting interface (brake drum/lining and drum/disc) will influence brake lining wear behavior. For example, the use of abrasives in the friction material may promote brake drum and/or brake disc wear, but the use of such materials may be required to achieve a needed brake effectiveness or to remove lining transfer layers or rust from the cast iron surface.

3.2.9 Friction Material Qualification

Qualification of friction materials for vehicle service usually involves both dynamometer and vehicle testing. Dynamometer experiments permit controlled, fully instrumented brake lining testing in a safe and cost-effective manner. Vehicle tests are conducted to verify the results obtained through full brake dynamometer experiments and to include the many conditions that are not suitably evaluated on a brake dynamometer. The next section of the report discusses test procedures to qualify friction materials.

3.3 Laboratory and Vehicle Friction Material Evaluation

Laboratory specimen testing machines are commonly used to characterize and audit the quality of friction materials, using specimens of full brake linings. The advantages of using laboratory systems for evaluation include: (1) automated testing, (2) careful control of operating conditions, and (3) faster measurement of brake lining characteristics. In addition, laboratory evaluations using a specimen test are less costly than full-scale brake dynamometer or vehicle experiments.

Numerous laboratory machine designs are used to determine friction properties[4]. Table 3 lists four of the most common test machines and test procedures generally used with each of these machines. The next section of the report briefly describes these four test machines.

TABLE 3. MACHINES FOR FRICTION MATERIAL EVALUATION (REFERENCE 3)

Apparatus	General Test Procedure
(1) Friction assessment screening test machine (FAST)	90 minute FAST QC test
(2) Friction materials test (FMTM)	SAE J661a quality control machine test procedure
(3) Girling scale dynamometer	Simulated vehicle road test
(4) Full brake inertia dynamometer	Simulated vehicle road test

3.3.1 Friction Assessment Screening Test (FAST)

The Friction Assessment Screening Test (FAST) machine was developed by Ford Motor Company specifically for rapid "fingerprinting" of friction material specimens. It is used for in-plant quality control of clutch facings and brake linings and some specialized friction material screening and diagnostic tests. A 0.50-inch-square specimen generally is used, but lining samples up to 1.00-inch-square can be tested. The small, flat sample assures rapid specimen seating to the flat, cast iron test disc (1.5-inch thick/7.1-inch diameter). Quality control (QC) tests run for 90 minutes, with the friction drag held to a constant value. With a constant rubbing speed (880 rpm) and constant friction drag, the horsepower dissipated is also constant, providing repeatable temperature-time histories (70 to 560 F for QC). QC tests are often run on every batch of friction material as the linings are finished at their manufacturing sites.

However, the small FAST specimen precludes confidently making correlations of laboratory performance with full brake behavior. Thus this machine is used primarily for routine brake lining QC testing. Specialized characterization test procedures are mostly proprietary, and require expertise for proper evaluation.

While this machine reportedly has been used to perform friction material screening tests, it never has been recommended as a substitute for full-scale brake evaluations.

3.3.2 Friction Materials Test Machine (FMTM)

This apparatus, developed by T. P. Chase of General Motors, uses an arc-shaped 1-inch-square specimen of brake lining material, which is forced against the internal surface of a rotating, 11-inch diameter, cast iron brake drum. Auxiliary heaters and air blowers are used to provide controlled brake drum heating and cooling rates.

The FMTM is also used for quality control testing. SAE has developed a recommended practice (SAE J661a) that is classified as a quality control test procedure on the FMTM. This test requires more test time and expense than the FAST QC procedure, since it includes simulated burnish, wear, effectiveness, fade, and recovery procedures. It is used more for periodic QC surveillance testing, than for routine production batch testing. General Motors and others also have developed specialized testing procedures for evaluating brake lining materials on the FMTM.

Based on the SAE J661a procedure, a brake lining friction rating specification has been required by some states for many years. However, this brake lining rating system has been shown to be clearly inadequate for meaningful comparative testing with different types of classes of friction materials. The SAE recommended practice J866 (revised in March 1985), includes this caution against such uses:

> Note: It is emphasized that this recommended practice does not establish friction requirements for brake linings, nor does it designate significant characteristics of brake linings which must be considered in overall brake performance. Due to other factors that include brake system design and operating environment, the friction coefficients obtained from this recommended practice cannot be reliably used to predict brake system performance."

Technical papers have pointed out that laboratory specimen tests, such as those which use the FMTM, do not provide acceptable correlation with actual vehicle or brake dynamometer service when non-asbestos or asbestos linings are evaluated. Different classes of non-asbestos brake linings, such as non-asbestos organic (NAO) and semimetallic (semimet), provide conflicting trends as well as different absolute values of friction on the Chase Machine[5].

3.3.3 Girling Scale Dynamometer

The Girling Scale Dynamometer is an apparatus which employs scaled-down brake components. A small brake disc is mounted on the end of a rotating shaft which carries inertia discs sized to ensure that the scaled disc pad will absorb the same amount of energy per unit area as a full-sized brake disc pad. The friction sample is pneumatically loaded against the rotating disc and a torque control system is used to produce a repetitive, constant deceleration drag.

Some brake characteristics scale by geometry and others are governed by absolute physical size. Consequently, experience is required when using a scale device to be assured that the scaling process itself has not altered performance characteristics of the brake assembly. Therefore this device, as well as the other specimen test devices, can produce good test results only when utilized by a person with expertise in such specialized tests.

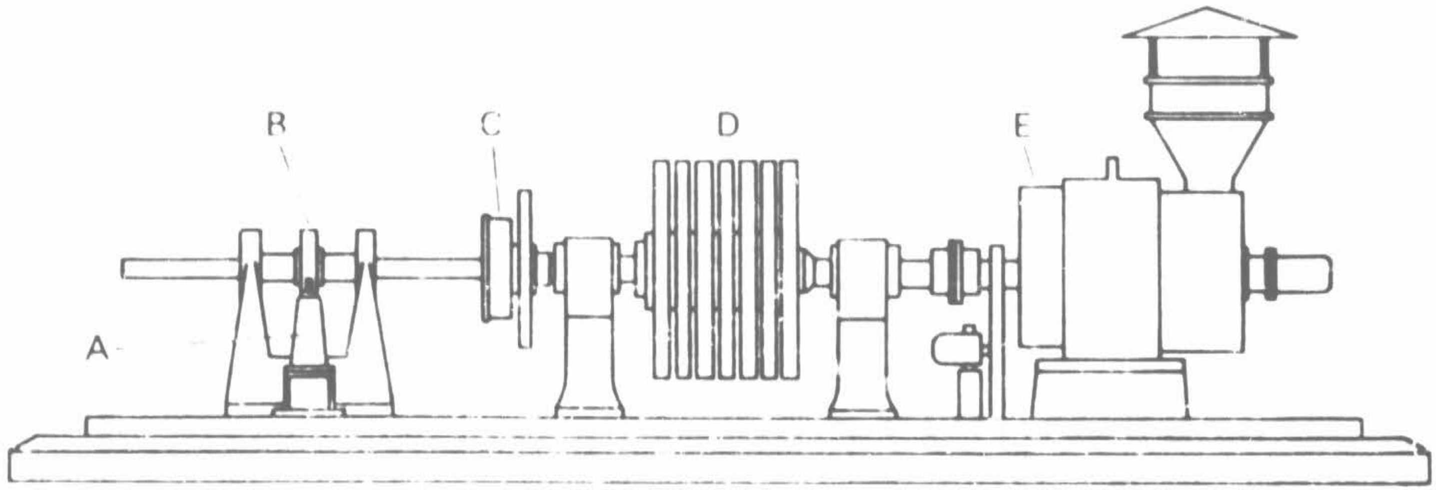
3.3.4 Full Brake Inertia Dynamometer

A full brake dynamometer simulates vehicle braking by mounting a complete brake assembly to a large rotating, inertially loaded shaft. The shaft's inertial loading is usually adjusted to simulate the actual road inertia. Figure 13 shows a schematic of an inertial dynamometer. Brake inertial dynamometers are designated by the number of ends, stations, or brake assemblies that can be tested at one time. Most are single ended for testing a single brake.

Double-ended dynamometers, while capable of simultaneous testing of two brakes, often are used as single-ended brake dynamometers so one test assembly can be installed as the other is being tested. Only a few four-ended brake dynamometers have been built. It is difficult on multiple station dynamometers to control the air flow for balanced brake cooling. Most brake dynamometers place the brake assemblies in closed ducts, both to expedite cooling and to control smoke and odor. Since faster cooling rates hasten testing, most dynamometer tests have much greater air flow and resultant cooling rates than are found in on-road testing. Consequently, brake dynamometers are used mostly for controlled wear tests, basic effectiveness tests, initial fade/recovery tests, and parking brake tests.

Full brake dynamometers are available in a range of sizes with inertial capacities ranging from "minicar" to "maxitruck". There are no standards, so almost every unit is different. Dynamometer-to-dynamometer differences in test results can be significant, even for carefully matched linings and brakes tested to the same inertia loading. Consequently, comparative brake lining test data is preferably obtained from a single brake dynamometer.

Much of the data difference between various dynamometers results from using brake lining thermocouples to control the brake test, as required



7.4 Inertia dynamometer. A: Hydraulic cylinder; B: Torque arm; C: Brake assembly; D: Flywheels; E: Motor.

FIGURE 13. SCHEMATIC OF INERTIA DYNAMOMETER

in the FMVSS 121 dynamometer procedure and as specified in most other procedures. Significant brake drum temperature variations occur with semimet and semimetallic linings, compared with conventional asbestos-based materials when control is by the lining temperature. Even different formulations of the same general type exhibit test drum temperature differences, especially if they vary in metallic content. Current brake testing practice now favors measurement of the cast iron temperature for test control. In this way differences of lining thermal conductivity do not significantly alter the temperature of the major heat sink, the drum or disc mass. Drum temperature measurement requires infrared pyrometry or thermocouple slip-ring assemblies. Most good brake dynamometers now permit one or both of these instrument refinements.

Burnishing conditions also affect the test results with most drum brake linings and blocks being sensitive to their initial usage history. When drum temperature control of the burnishing operation is provided, the test results are clearly better.

It now appears possible, with proper instrumentation and good control on the burnishing procedure, to perform meaningful friction material screening tests on full brake dynamometers.

Except for replicating airflow over the brake and environmental conditions, such as water and dust contamination, full brake dynamometers now can closely duplicate most vehicle in-service braking conditions and are invaluable for brake diagnostic testing. They can be excellent for initial brake lining screening tests. However, they are not sufficient to fully evaluate the acceptability of substitute brake linings.

3.4 Correlation of Laboratory Test Results With Vehicle Test Results

Numerous studies have been done to determine the correlation between laboratory friction material test results and actual vehicle test results[4,5,6,7,8]. In general, the only good analogy of a vehicle brake is the brake itself. Consequently, there are no specimen or scale test devices that can consistently yield test data that correlates with full vehicle performance data. This does not mean that such laboratory tests are useless--just that they should not be used to predict field performance behavior. They can and have been used to screen friction material for undesirable performance flaws.

Even tests on full brake dynamometers are difficult to correlate with on-road vehicle brake performance unless careful instrumentation and test controls are used. It should be possible to correlate full brake dynamometer test results with on-road data without need for questionable correction factors. This has been attempted by many, published by few, but not yet verified by anyone.

3.5 Federal Braking Requirements and Other Brake Tests

As indicated in previous sections, the qualification of vehicle brake systems and friction materials can involve numerous experiments to determine effectiveness, stability, fade resistance, moisture sensitivity, wet friction, and other performance parameters. Some of the brake performance criteria are determined by Federal Motor Vehicle Standards (105-83 and proposed 135 for hydraulic brakes, 121 for air brakes), while other performance standards are determined principally by the standards of the vehicle and friction product manufacturers.

This section of the report discusses the Federal Motor Vehicle Safety Standards now in effect and proposed for hydraulic and air brakes. In addition, some of the numerous SAE brake test procedures used to evaluate brake system and friction product performance will be discussed.

3.5.1 Federal Motor Vehicle Safety Standard 105

This federal standard mandates hydraulic and parking brake performance under specific vehicle operating conditions. Under the provisions of this standard vehicles under 10,000 lbs gross vehicle weight are tested to one set of procedures, while vehicles over 10,000 lbs gross vehicle weight are tested to a different set of procedures. General specifications are designed around stopping distances for braking with minimal tire skidding. Brake use tends to modify friction material performance. For this reason specifications are listed for new (pre-burnished) and conditioned (burnished) friction materials.

FMVSS 105 outlines braking requirements for vehicles braking under level, straight, dry, clean pavement conditions. Requirements for vehicle wet braking as well as parking brake performance on grades are also outlined. Table 4 lists the general categories of tests and the evaluation criteria used to determine brake performance. Specific braking requirements are outlined in the following section.

3.5.1.1 Stopping Distance Requirements. FMVSS 105 outlines a series of tests for brake effectiveness and dictates required stopping distances without wheel lock-up for passenger cars, vehicles (non-passenger cars) with GVWR of less than 8,000 lbs, vehicles weighing between 8,000 and 10,000 lbs, and vehicles with a GVWR of greater than 10,000 lbs. The procedures describe required performance for new brake linings and for burnished linings that have accumulated a specified history of brake performance. Performance requirements for partially disabled brake systems also are outlined.

Appendix A lists the procedures for evaluating braking system stopping distances under "normal" braking duty. The performance under brake fade conditions is determined by measuring the brake pedal force required to stop the vehicle under severe braking conditions.

3.5.1.2 Parking Brake Requirements. The vehicle parking brake must be capable of holding the vehicle stationary for 5 minutes on a grade (30 percent for cars, 20 percent for light trucks and vehicles over 10,000 lbs). This can be accomplished in part by using the transmission to brake the vehicle, provided the parking mechanism in the transmission must be engaged before the ignition key can be removed.

With respect to replacement friction materials, the ability of alternative materials to provide static friction levels sufficient to satisfy these criteria can only be assessed by actual vehicle tests.

TABLE 4. TESTS AND PERFORMANCE CRITERIA SPECIFIED UNDER FMVSS 105

Test	Performance Criteria	General Test Conditions
(1) Effectiveness	Stopping Distance	• Before and after burnish • GVWR and empty • With and without failures • Before and after spike stops • Before and after fade
(2) Fade tests	Pedal force and deceleration	• Pedal force needed to hold required deceleration in repeated stops to heat brakes • Pedal force during cool down (recovery) • (Did brakes return to normal?)
(3) Wet brakes	Pedal force and deceleration	• Pedal force needed to hold deceleration after brakes are wet • (Did brakes return to normal?)
(4) Parking brake	Pedal force/lever force	• Hold on grade with specified application force

3.5.2 Federal Motor Vehicle Safety Standard 121

Federal Motor Vehicle Safety Standard 121 lists the performance requirements for air braking systems. These systems are commonly used in heavy trucks, tractor-trailer combinations, off-road vehicles, and transit buses. This federal standard specifies requirements for stopping distance, brake effectiveness, fade and recovery, brake actuation time, brake release time, and parking brake operation. For these vehicles, brake loading can vary considerably, depending upon the service conditions and cargo load carried by the truck or trailer.

This section of the report will be concerned with stopping distance requirements and vehicle/dynamometer experiments needed to determine these requirements. Currently under FMVSS 121 only intercity and transit buses are required to meet stopping distance requirements. All other vehicles are exempt and do not require vehicle tests to satisfy FMVSS 121.

3.5.2.1 Vehicle Braking Experiments. Vehicle braking tests are conducted on level surfaces exhibiting different friction properties (as indicated by pavement skid numbers). For example, an 80 skid number refers to a generally dry, concrete surface, while a 30 skid number refers to a wet, polished concrete surface. Vehicle loads are adjusted to replicate heavy (loaded) or light (unloaded) conditions. Brakes are evaluated by braking the vehicle from 60 mph and 30 mph on a dry surface with a skid number of 81 and by braking the vehicle on a wet surface with a skid number of 30. Both dry and wet pavement braking are conducted under empty and fully loaded conditions.

Braking road test procedures for FMVSS 121 are listed in Appendix A. Note that in contrast with FMVSS 105 no decelerations are designated. Road tests with new brakes are preceded by a brake burnishing procedure consisting of 500 brake applications. During burnishing, brake lining temperatures are restricted to 500 F ± 50 F (Note that brake drum temperature is not controlled--see 3.2.4).

In addition to the regular system brakes, the vehicles must have emergency braking systems capable of stopping the vehicle in the event of partial brake system failure. This requirement is similar to the FMVSS

105 requirements describing brake operation in the event of partial loss of hydraulic fluid.

3.5.2.2 Parking Brake Test. The parking brakes for trucks, buses, and tractor-trailer combinations must be capable of holding the vehicle on a 20 percent grade, on a concrete surface, under both empty or fully loaded conditions in both directions. Initial brake application can be achieved using air or hydraulic activators. Once actuated the application braking loads must be maintained solely by mechanical means.

3.5.2.3 Dynamometer Testing for FMVSS 121. FMVSS 121 describes procedures for inertia dynamometer evaluation of friction materials. These procedures require the installation of a complete air brake assembly on the inertia dynamometer. Since stopping distance requirements cannot be measured using an inertia dynamometer, brake performance is determined by measuring brake torques and deceleration rates as a function of air pressure in the actuator. Dynamometer inertia is determined by using the inertial equivalent to the vehicle load on each axle.

The dynamometer test sequence for determining brake retardation, brake power, and brake recovery is listed in Appendix A. Trailers are only required to pass brake retardation requirements. Service line pressure and calculated brake retardation factor are used to determine acceptability of the materials.

3.5.3 Proposed Motor Vehicle Vehicle Safety Standard 135

This standard would replace FMVSS 105 for hydraulic brakes for passenger cars only. It contains a shortened test procedure designed to be more harmonized with European regulations. Requirements posed by the new standard which may affect friction material qualification are described in the following sections. This proposed standard can be found in Federal Register, May 10, 1985, Vol. 50, No. 91, pp. 19744 through 19760. Later revisions are in FR, Jan 14, 1987, Vol. 52, No. 9, pp 1474 through 1474.

<u>3.5.3.1 Front Brake Biasing</u>. Under FMVSS 135 standard, brake balancing would have to be adjusted to ensure that in the event of a braking situation resulting in wheel lock-up, the front wheels will lock first, for both a lightly-loaded vehicle and a fully-loaded vehicle. Currently, FMVSS 105 does not specify a wheel lock-up sequence. The braking situation involves careful selection of friction materials exhibiting stable, repeatable friction performance coupled with a properly adjusted proportioning valve. A vehicle designed with front-bias braking could become unsafe over time if the brake balance significantly changed.

<u>3.5.3.2 Control Forces for Brake Application</u>. Under the proposed standards, the allowable pedal forces required to brake the vehicle under specified stopping conditions will be reduced. Lower control forces may necessitate redesign of brake components on some cars to provide greater mechanical advantage, particularly to meet the requirements for performance with a failed power assist unit.

<u>3.5.3.3 Parking Brake Performance</u>. Under the proposed standard, the test gradient would be reduced from 30 percent to 20 percent, and a dynamic test has been added. The allowable control force for applying the parking brake would be reduced. This particular requirement may not place additional restrictions on friction material performance. A grade reduction from 30 percent to 20 percent represents a 30 percent reduction in load applied via gravity in the direction of slope. In contrast, the proposed reduction in allowable control force for the parking brake is between 10 and 20 percent.

3.5.4 SAE Recommended Practices for Evaluating Brake Systems and Friction Materials

The Society of Automotive Engineers (SAE) has developed about 26 recommended practices for checking the performance of brake lining systems. These standards cover automobile, truck, and trailer brake system tests using both vehicles and dynamometers.

Prior to the adoption of FMVSS 105 and 121, the SAE procedures were intended to give some suggested standard guidelines to brake system evaluations. The enactment of FMVSS 105 as a requirement for brake system certification shifted the emphasis of these SAE procedures to the role of supplementary tests that could be used to further qualify vehicle brakes and braking systems.

Table 5 lists some of the SAE brake test code procedures. Various SAE documents outline test procedures, while others outline performance requirements for various vehicle classes.

TABLE 5. SELECTED SAE VEHICLE BRAKE TEST CODES

SAE Code	Description	Comments	Vehicle Affected	Approval Date
J661a	Laboratory procedure for evaluating friction	Generally shown to have poor correlation with vehicle performance		5/1953 - revised 9/1971
J667	Laboratory procedure for evaluating friction material performance using an inertial dynamometer	First SAE recommended practice for inertia dynamometer testing		4/195? - revised 6/1961
J843d	Vehicle test procedure for evaluating brake system performance	Intended to replicate conditions of vehicle tests required by FMVSS 105	Passenger cars and light duty trucks	1/1963 - revised 3/1973
J201	In-use vehicle test procedure for brake system of cars, light trucks, and passenger vehicles up to 10,000 GVWR	An inexpensive quick test designed to examine, in a cursory fashion vehicle parking brakes and service brakes; set up for state inspection stations	Passenger cars and light duty trucks	4/1976
J212 JUN80	Laboratory test procedure for dual-end inertia dynamometer	Laboratory (inertia dynamometer) version of SAE J843b	Passenger cars and light duty trucks	6/1980
J880 MAR85	Brake system rating test code	Rates power absorption capability of heavy duty vehicle brakes	Commercial vehicles	3/1985

4.0 PERFORMANCE ATTRIBUTES OF FRICTION MATERIALS NOW IN USE

4.1 Section Summary

This section presents some performance characteristics of known asbestos and asbestos-free friction materials and discusses the feasibility of replacing the asbestos-based brake linings that are currently used.

Main points brought out in this section include:

- Friction materials are proprietary formulations, made from specific combinations of binder resins, reinforcing agents, fillers, and friction modifiers to provide acceptable performance in some brake applications.
- Chrysotile asbestos-based friction products have been highly developed and refined over the past 80 years. Their field performance attributes are well known.
- Non-asbestos friction materials presently are under intensive development, but most have been conceived within the past decade. Limited field service data is available.
- Four classes of non-asbestos friction products exist: non-asbestos organic (NAO), resin-bonded metallic (semimetallic), sintered metallic, and carbon-carbon. Only the semimetallic and NAO materials have shown promise for common automotive brake lining applications. Semimetallic linings are not readily applicable to drum brakes, except for heavy truck brake blocks.
- Non-asbestos organic linings offer the best potential for most automotive friction material applications. However, development of NAO materials is hampered by a lack of understanding of the new raw materials, specifically their special processing requirements and their full-service performance behavior. Since lining formulation is a proprietary process, there is very little information interchange on non-asbestos lining technology.
- No performance requirements exist for aftermarket friction products. Consequently, non-asbestos brake linings are

commercially available, but they lack field service data to assure satisfactory performance for the full range of automotive applications.

4.2 Introduction to Friction Material Formulations

Little has been published about the specific formulations of friction materials, since they are considered to be proprietary compositions by the friction material manufacturers. This section of the report reviews the more common forms of both asbestos and non-asbestos lining materials and presents data regarding performance under vehicle or simulated vehicle braking conditions.

Friction materials for automobiles contain four general types of ingredients: reinforcing agents--usually fibers, friction modifiers, fillers, and binders. Most automotive friction materials use thermosetting resins in their binder systems. These resins, often of the two-step (Novolac) phenolic type and generally modified for both processing and functional purposes, provide the matrix to bond the various constituents together. Internal pressures generated during processing and fade testing can reach 1000 psi, so binder resins require good tensile strength at elevated temperatures. Binder resins provide more than just structural attributes to the brake lining. Thermal stability, friction level, fade, fade recovery, dimensional stability, wear life, and other performance characteristics of the brake lining are determined, at least in part, by the choice and amount of binder resin.

Reinforcing agents provide the structural elements to support the friction material in service. Brake linings experience a range of loadings that require strength, stiffness, and toughness. The reinforcing agents contribute to the stiffness and strength of the friction material composite. Usually these agents are fibrous and most often provide other attributes to the brake lining, such as wear resistance and improved dimensional stability.

Since chrysotile asbestos has been used as a reinforcing agent in friction materials for about 80 years, its performance attributes are fairly well known. Chrysotile asbestos was chosen because of its unique combination of physical, thermal, mechanical, tribological, processing, and economic properties. It is a unique mineral, processed to provide the desired fiber length distribution and fiber "openness" (degree of fiber fluffing or opening of the fiber bundles) needed for specific applications. Usually two or more grades of chrysotile asbestos are blended to produce the desired properties for the brake lining.

Non-asbestos friction materials use a blend from several hundred potential fiber and other structural agents that have been tried in brake linings. No one fiber replaces asbestos, so a "fiber cocktail" is developed to provide the needed processing, structural, functional, and permeability attributes for the brake lining at an acceptable cost.

Friction modifiers and fillers, as the names suggest, are added to provide the needed performance modifications and cost control to the binder/fiber system. Hundreds of organic and inorganic constituents may be used, in varying amounts, distributions, and particle sizes to achieve the intended results. Since friction material formulation is more of an art than science, it is common for these materials to be sequentially added to the formulation to "correct" different performance shortcomings in the lining development process.

The asbestos-free friction materials have four developmental classes: non-asbestos organic (NAO), semimetallic (semimet), sintered metallic, and carbon-carbon. Semimetallic and NAO linings appear to be the best suited for most automotive brake applications, but all four types will be discussed in Section 4.4.

4.3 Asbestos-Based Friction Materials

Asbestos has been used in brake linings and other friction products since the turn of the century, when metals, leather, and wood no longer were adequate. The predominant type of asbestos used in brake linings is chrysotile, a hydrated magnesium silicate. The ultimate chrysotile fibril is about one millionth of an inch in diameter, so a fiber bundle about the size of a human hair may contain a million fibrils. The larger fiber bundles, called "crudes" constitute the visible asbestos in a friction material. Smaller fibers, especially when fully wetted by the binder resin, are virtually impossible to see in the brake lining. Many lengths and fiber diameters are used in making the asbestos-based friction materials, usually by selection of an appropriate commercial grade or grades and by proper blending. Asbestos provides many desirable attributes to the linings, both in manufacture and in service usage.

During the mixing and molding process, asbestos helps to hold the materials together. This is referred to as "green strength" in the preforming and molding operations. During molding, and also during usage, the asbestos provides permeability to the lining, letting internally generated volatiles escape before they can produce high internal pressures and possibly blister or crack the brake linings.

Chrysotile asbestos, being hydrated, loses this water as the temperature rises. At around 650 degrees Celsius (about 1200 degrees F) this dehydroxylation causes about a 14-percent weight loss to the asbestos. At slightly higher temperatures, the chrysotile asbestos converts to an amorphous or glassy phase. One common product of this conversion is called forsterite. In this converted phase, the chrysotile asbestos normally has been transformed from a fiber to a very fine powder. At very high temperatures, forsterite can deposit in smeared layers over the disc or drum braking surfaces, but this is quite uncommon and undesired.

Each vehicle application requires friction materials exhibiting different frictional and mechanical properties. Passenger car and light truck drum brake linings, called segments, usually contain from 30 to 70 percent by weight of asbestos. If held together with a liquid resin, these are referred to as wet mixes. Such materials are commonly roll-molded to their basic cross-sectional shape, but also may be formed by extrusion or other molding processes. When a powdered binder resin is used, the mix is referred to as a dry mix. These generally require an initial molding or briquetting operation to produce the required shape. Both are cured by heat in a process that is both time and temperature dependent.

A wide range of friction, wear, and other properties can be built into such materials, particularly with over 70 years of formulation development time. Asbestos provides good static friction properties, important to drum brakes with integral parking brakes, and is easily formed, by many processes, to make durable and dimensionally stable segments.

Passenger car and light truck disc brake linings are almost exclusively made with powdered binder resins in dry mix processes that involve being individually molded to nearly final dimensions. Asbestos content usually is a bit lower and longer fiber lengths are used in disc brake linings because of their greater temperatures and pressures in service usage. The permeability, or "breathing" characteristic, of chrysotile asbestos is important to disc brakes to prevent rapid friction loss with increasing temperatures and during hard, high speed stops.

Heavy truck drum brake linings are called blocks and are generally molded in slabs. Longer fiber length asbestos and added crude fiber content is needed in these blocks, for reasons similar to those for disc brakes. Truck blocks are thick, about 0.75 inches (19 mm) so they require sufficient permeability to release volatile materials from manufacturing as well as from hard brake usage. Inadequate "breathing" causes blistered or delaminated brake linings. Truck brake blocks have been continuously refined over the years, with special formulations for most of the unique usage conditions.

4.4 Non-Asbestos Friction Materials

Less than twenty years have been devoted to the development of non-asbestos brake linings, with the most intensive effort over the past ten years. Various alternative fibers have been studied since cotton was replaced by asbestos 80 years ago. However, none provided the requisite performance to challenge asbestos until the semimetallic linings were developed for hard service disc brake usage in the 1970's.

Concerns about asbestos fiber toxicity, increasingly stringent air quality standards in asbestos manufacturing plants, and rising insurance costs all stimulated the development of substitute materials. Substantial progress appears to have been made in the past few years, as many new vehicle models have been released with fully asbestos-free brake systems. Several aftermarket friction products have been advertised as asbestos-free, but little is known of their actual service performance characteristics.

Dynamometer and vehicle performance test data for non-asbestos friction materials were not made available to us during the preparation of this report, so a complete evaluation of these materials was not possible. A variety of non-asbestos materials is available for aftermarket applications. No replacement friction materials, except qualified OEM linings, are known to have undergone qualification tests under FMVSS 105. In addition, most aftermarket suppliers lack the facilities required to conduct FMVSS 105 and FMVSS 121 test procedures.

The following discussion, though not complete, provides at least an introduction to the different types of non-asbestos friction materials that are presently available or under development. Some of their basic functional characteristics are also given, when sufficient information was available.

Despite substantial engineering efforts, non-asbestos replacement friction materials are not available, at a proven quality and performance level that is equivalent to that of the original brake linings, for vehicles which originally were released with asbestos-based brake linings.

Non-asbestos friction materials technology is advancing rapidly, with many new car, light truck, heavy truck, and off-road brake systems being released for new vehicle production. Materials are under development for all four general classes.

4.4.1 Semimetallic Friction Materials

Semimetallic and resin bonded metallic (RBM) are all names for this popular class of friction material. Semimetallics utilize steel wool, some form of iron powder, graphite, binder resin, and various other constituents in their formulations.

Semimetallics have been used as disc brake linings on passenger cars and light trucks for about a decade. Presently they are the most common friction material used with original equipment manufacturer (OEM) disc brakes in the United States. Although originally produced with a resin-asbestos backing layer, most semimetallic linings now use no backing layer, or one of a non-asbestos organic (NAO) composition. Semimetallic linings also have had limited usage in heavy truck drum and disc brakes.

These friction materials are usually hot-pressed to finished dimensions. Consequently, they are not readily made into drum brake segments, due to the needed large lining curvature. Since semimetallics also tend to be low in strength and stiffness, they are better suited to the thicker disc brake lining and heavy truck block configurations.

Semimetallic linings have several unique performance characteristics. For one, they have a high initial wear rate, at least until a ferrous transfer layer is built up onto the drum or disc cast iron surface. This formation is rapid at high temperatures, but can be quite slow for brakes that operate at low temperatures, low speed, and light pressures. Lining wear life is greatest for moderate temperature service. Poor lining life can result from very low usage temperatures, so brakes are often designed to run hotter with semimetallic linings. Most friction materials have a lower friction level at higher rubbing speeds, but semimets do not. These materials have nearly constant friction levels from about 30 mph to beyond 100 mph, providing potential front-to-rear brake balancing difficulties for some systems. While the friction is nearly constant at high speeds, the lining wear rate is not. Semimetallic linings have high wear rates, per unit work done, at higher rubbing speeds. Thus they seldom are used for racing car applications.

Water affects many friction materials greatly, but has very little influence on semimetallics--unless accompanied by oil. Water and oil can act to reduce the friction of semimet materials in contact with cast iron discs. Since road splashing generally contains some oil, this can cause a loss of friction. Disc brakes are less water sensitive than are most drum brakes and often run warm enough to dry quickly, so water effects usually are not critical or long lasting. Cool and humid ambient air conditions affect semimetallic linings significantly, causing a temporarily low brake effectiveness called "morning sickness".

4.4.2 Non-Asbestos Organic Friction Materials

Non-asbestos organic (NAO) materials utilize a combination of fibers and other ingredients to fulfill the functions that chrysotile fibers had performed in resin-asbestos linings. Aramid (DuPont's Kevlar), fiberglass, mineral wool, wollastonite, steel wool, and processed mineral fiber are some of the common reinforcement fibers used along with the binder resin and various fillers and friction modifiers in NAO brake linings.

NAO brake lining formulations presently are used in some OEM drum brake applications for passenger cars and light trucks and increasingly are used in brake blocks on heavy truck drum brakes. NAO disc brake linings have been released for many OEM disc brake applications. Development efforts of NAO drum brake segments for the remaining OEM applications remains active.

This class of friction materials offers the greatest hope as an effective asbestos replacement, but also provides the greatest problems to develop. Literally hundreds of fibers and reinforcing agents have been used, generally in combination with several others. Finding the best combination for lining processability, friction level, friction stability, wear life, fade resistance, recovery, contamination sensitivity, and mechanical properties is a formidable task, even using statistically designed experiments. Since there is essentially no technical communication or cooperation among the lining suppliers, each is working virtually independently at this task. It appears likely that new NAO materials will be developed that are superior to the best of the asbestos-based linings. Presently, NAO materials tend to be hard, brittle, low in permeability, highly anisotropic, and prone to hot spot, blister, and crack in service.

4.4.3 Sintered Metallic Friction Materials

Usually sintered, these heavy-duty materials typically are of iron or copper base, but they may generally contain inorganic filler and friction modifiers as minor constituents.

Sintered ferrous drum brake linings were released for a few OEM passenger car applications two decades ago. They tend to be environmentally sensitive, both to temperature and moisture, which limits commercial applications. However, they are used for special service aftermarket automobiles, some severe service commercial vehicles, and aircraft disc brake applications.

Sintered copper-based friction materials have been used in heavy duty brakes and clutches for around three decades. Often with another metal, forming a bronze, and a refractory, such as mullite, these materials can perform well in hard service usage. However they too are environmentally sensitive and can cause severe galvanic corrosion in wet environments, when used against the typical grey cast iron countersurface materials. Aircraft disc brakes and heavy duty truck/tractor clutches are present uses for the sintered bronze friction materials.

No known new application of these relatively old and well developed friction materials has resulted from the search for asbestos substitutes, largely due to their cost and sensitivity to light-duty environmental conditions[9].

4.4.4 Carbon-Carbon Friction Materials

These materials are space-age composites of carbon (graphite) fiber, held in a matrix of amorphous carbon using a costly and time-consuming manufacturing process.

Military aircraft, race cars, and some commercial aircraft now sometimes use the carbon-carbon friction materials for both the stationary and rotating elements of disc brakes. High cost and environmental sensitivity have limited additional applications[9]. Recent developments of lower cost carbon fibers may increase their use in vehicle applications.

4.5 Aftermarket Vehicle Considerations

4.5.1 Drum Brakes

Brake design also affects the suitability of using some friction materials. The duo-servo drum brake used in older U.S. vehicles usually employs two different types of linings, with different friction properties, on a single brake to maximize overall brake performance. Aftermarket friction materials must be capable of replicating original design friction levels and friction stability to achieve acceptable vehicle braking performance.

The leading-trailing drum brake used on the rear axle of the new, smaller front wheel drive vehicles does not require friction materials with such stringent friction stability properties. In both applications, the static friction properties of the material are important due to the use of rear drum brakes as parking brakes.

4.5.2 Disc Brakes

Disc brakes generally operate at higher temperatures than do drum brakes, and the friction material used for this application must exhibit stable friction behavior over a wide temperature range. U.S. passenger cars and light truck disc brakes which used asbestos-phenolic friction materials were designed to operate at lower temperatures than do present vehicles that use semimetallic linings. These asbestos-based linings generally had higher friction, especially at the lower brake temperatures, than do the semimetallic linings.

4.5.3 Factors Affecting Substitution of Friction Materials

The use of asbestos-free materials as direct substitutes in vehicles designed for asbestos-based linings may be restricted for the following reasons:

(1) **Braking balance between front and rear brakes may be adversely affected.**

With few exceptions, semimetallic and NAO linings presently are the only non-asbestos friction materials available for use on disc brakes. Use of semimetallic linings would decrease the front brake effectiveness, especially at the lower temperatures. Since many of the front brakes were designed to operate at lower temperatures than are optimal for semimetallics, the semimetallic linings would not provide proper friction and wear behavior for many users.

The available NAO rear brake linings differ in their friction properties, especially in the low temperature region, and also may be humidity sensitive. Front-rear brake balance at low temperature could be unsatisfactory, unless matched front and rear linings both were installed during brake servicing. Regrettably, many users have only one set of linings replaced at a time. This offers a substantial opportunity for unbalanced braking between the front and rear brakes.

No known balanced non-asbestos brake lining sets are available for the aftermarket applications that originally were asbestos-based. The front-rear balance with replacement asbestos-free linings probably will be sensitive to the brake temperature, vehicle speed, and brake line pressure.

(2) Parking brake capacity may be reduced.

Many of the non-asbestos organic (NAO) drum brake linings provide low effectiveness at low temperatures. In addition, they also generally have high thermal expansion coefficients and are stiffer in compression. This can lead to a loss of parking brake capacity both from the lower effectiveness values and from larger losses of input cable forces, due to lining contraction.

(3) No meaningful brake lining effectiveness ratings exist.

NAO friction materials are currently produced domestically in both brake pad and brake drum configurations. Tables 6 and 7 list current U.S. producers of brake pads and linings for passenger cars and trucks[10]. Only a third of the manufacturers of NAO brake linings for light and medium vehicles are outfitted with the facilities needed to evaluate friction products under true vehicle test conditions or simulated vehicle tests (full brake inertia dynamometers). Similarly, only a third of the manufacturers of heavy vehicle drum brake blocks have appropriate test facilities for evaluating their NAO friction materials. All of these suppliers rate their linings using a rating methodology that has been shown to be deficient (see Section 3.2.2).

TABLE 6. PRODUCERS OF BRAKE LININGS FOR LIGHT AND MEDIUM VEHICLES

Company	Location	Market	Products: Disk Brake Pads: Asbestos	Products: Disk Brake Pads: Semi-Metallic	Products: Disk Brake Pads: NAO	Products: Drum Brake Linings: Asbestos	Products: Drum Brake Linings: NAO	1983 Sales (million dollars)	Employees	Comments
Abex Corp.	Winchester, VA	OEM and aftermarket	X	X		X	X	12	200	
Bendix Corp.	Troy, NY	OEM and aftermarket	X	X	X	X	X	75	1,200	Aftermarket products contain asbestos
Friction Div. Products, Inc.	Trenton, NJ	OEM and aftermarket		X		X		10-12*	N/A	1 million disc pads 400-500 thousand drum pieces produced per month
General Motors (Delco Moraine Division)	Dayton, OH	OEM and aftermarket	X	X				400	4,000	OEM for GM and Saab
General Motors (Inland Div.)	Dayton, OH	OEM and aftermarket				X	X	N/A	N/A	Also produces semi-metallic drum brake lining
H. Krasne Mfg. Co. Inc.	Los Angeles, CA	Aftermarket for imported cars	X	X				N/A	N/A	
Lear Siegler, Incorporated	Danville, KY	Primarily aftermarket: some OEM for medium trucks	X	X				50*	400*	
Nuturn	Smithville, TN	OEM and aftermarket	X	X		X	X	12	200	
Auto Friction Corp.	Lawrence, MA	Aftermarket, imported and domestic vehicles	X	X		X	X	8	100	
Brake Systems, Inc.	Stratford, CT	OEM and aftermarket		X	X	X	X	N/A	N/A	

TABLE 6. PRODUCERS OF BRAKE LININGS FOR LIGHT AND MEDIUM VEHICLES

Company	Location	Market	Products: Disk Brake Pads: Asbestos	Products: Disk Brake Pads: Semi-Metallic	Products: Disk Brake Pads: NAO	Products: Drum Brake Linings: Asbestos	Products: Drum Brake Linings: NAO	1983 Sales (million dollars)	Employees	Comments
Abex Corp.	Winchester, VA	OEM and aftermarket	X	X		X	X	12	200	
Bendix Corp.	Troy, NY	OEM and aftermarket	X	X	X	X	X	75	1,200	Aftermarket products contain asbestos
Friction Div. Products, Inc.	Trenton, NJ	OEM and aftermarket		X		X		10-12*	N/A	1 million disc pads 400-500 thousand drum pieces produced per month
General Motors (Delco Moraine Division)	Dayton, OH	OEM and aftermarket	X	X				400	4,000	OEM for GM and Saab
General Motors (Inland Div.)	Dayton, OH	OEM and aftermarket				X	X	N/A	N/A	Also produces semi-metallic drum brake lining
H. Krasne Mfg. Co. Inc.	Los Angeles, CA	Aftermarket for imported cars	X	X				N/A	N/A	
Lear Siegler, Incorporated	Danville, KY	Primarily aftermarket: some OEM for medium trucks	X	X				50*	400*	
Nuturn	Smithville, TN	OEM and aftermarket	X	X		X	X	12	200	
Auto Friction Corp.	Lawrence, MA	Aftermarket, imported and domestic vehicles	X	X		X	X	8	100	
Brake Systems, Inc.	Stratford, CT	OEM and aftermarket		X	X	X	X	N/A	N/A	

TABLE 6. PRODUCERS OF BRAKE LININGS FOR LIGHT AND MEDIUM VEHICLES (Continued)

			Products							
			Disk Brake Pads			Drum Brake Linings				
Company	Location	Market	Asbestos	Semi-Metallic	NAO	Asbestos	NAO	1983 Sales (million dollars)	Employees	Comments
U.S. Automotive Mfg. Co.	Tappahannock, VA	Aftermarket	X			X		N/A	N/A	
Carlisle	Ridgeway, PA	Aftermarket				X				
Chrysler	Wayne, MI	OEM and aftermarket	X	X		X				
Virginia Friction Products	Walkerton, VA	Aftermarket	X	X		X				

* Figures provided by company representatives

Sources: ICF 1986 Survey of Primary and Secondary Processors of Asbestos Products. Telephone conversations with company representatives.

Sales and employees -- Ward's Directory of 51,000 Largest U.S. Corporations and Ward's Directory of 49,000 Private U.S. Companies. 1984. Petaluma, CA: Baldwin H. Ward Publications.

TABLE 7. PRODUCERS OF BRAKE LININGS FOR HEAVY VEHICLES

Company	Location	Market	Disc Brake Pads Semi-Metallic	Drum Brake Blocks: Asbestos	Drum Brake Blocks: NAO	Drum Brake Blocks: Full-Metallic	Drum Brake Blocks: Metallic (Asbestos-Free)	1983 Sales (million dollars)	Employees
Abex Corp.	Winchester, VA	OEM and aftermarket		X	X			12	200
Bendix Corp. Heavy Vehicles Systems	Cleveland, TN	Aftermarket	X	X	X	X	X	N/A	N/A
Carlisle Corporation	Ridgway, PA	OEM and aftermarket	X	X	X		X	25	400
H.K Porter Co.	Huntington, IN				X			18	300
Nuturn	Newcastle, IN	OEM and aftermarket		X	X			12	200
Ordnance Parts and Engineering	Fort Worth, TX	OEM and aftermarket, primarily military vehicle		X				2*	N/A
Brake Systems, Inc.	Stratford, CT	OEM and aftermarket			X			N/A	N/A
Scan Pac	Mequon, WI	OEM and aftermarket			X			N/A	N/A
Wheeling Brake Block Mfg. Co.	Wheeling, WV	OEM and aftermarket			X			5	100
Raymark	Crawfordsville, IN	OEM and aftermarket		N/A	N/A	N/A			
Standco Ind.	Houston, TX	N/A		X					
Palmer Prod.	Louisville, KY	N/A		X	X	X			
Friction Prod.	Medina, OH	OEM and aftermarket							

* Figures provided by company representative

This test, with 1 inch square specimens, can give particularly misleading friction data for some NAO and semimet brake linings.

The brake lining/drum or disc/pad system is a tribological system in which alterations in either the pad surface or the rotor surface affect system frictional behavior. Under elevated temperatures, cast iron surfaces can form iron oxides or develop transfer films which exhibit lower coefficients of friction than do plain cast iron surfaces. The abrasive nature of asbestos-phenolic friction materials acts to continually remove these surface films, thus restoring system friction and brake effectiveness. Semi-metallics, on the other hand, depend on a transfer film that is known to exhibit low friction under cold and moist conditions.

4.6 Direct Comparison of OEM and Aftermarket Brake Linings

Complete brake dynamometer and vehicle performance data are not generally available to use for comparisons of different friction materials, making it difficult to support or refute claims made about the availability of acceptable, asbestos-free replacement brake linings. When available, interpretation and evaluation of the test data can be difficult.

The next two sections present both dynamometer data and vehicle test data that highlight observed performance limitations posed by the use of non-asbestos friction materials.

4.6.1 Dynamometer Test Data

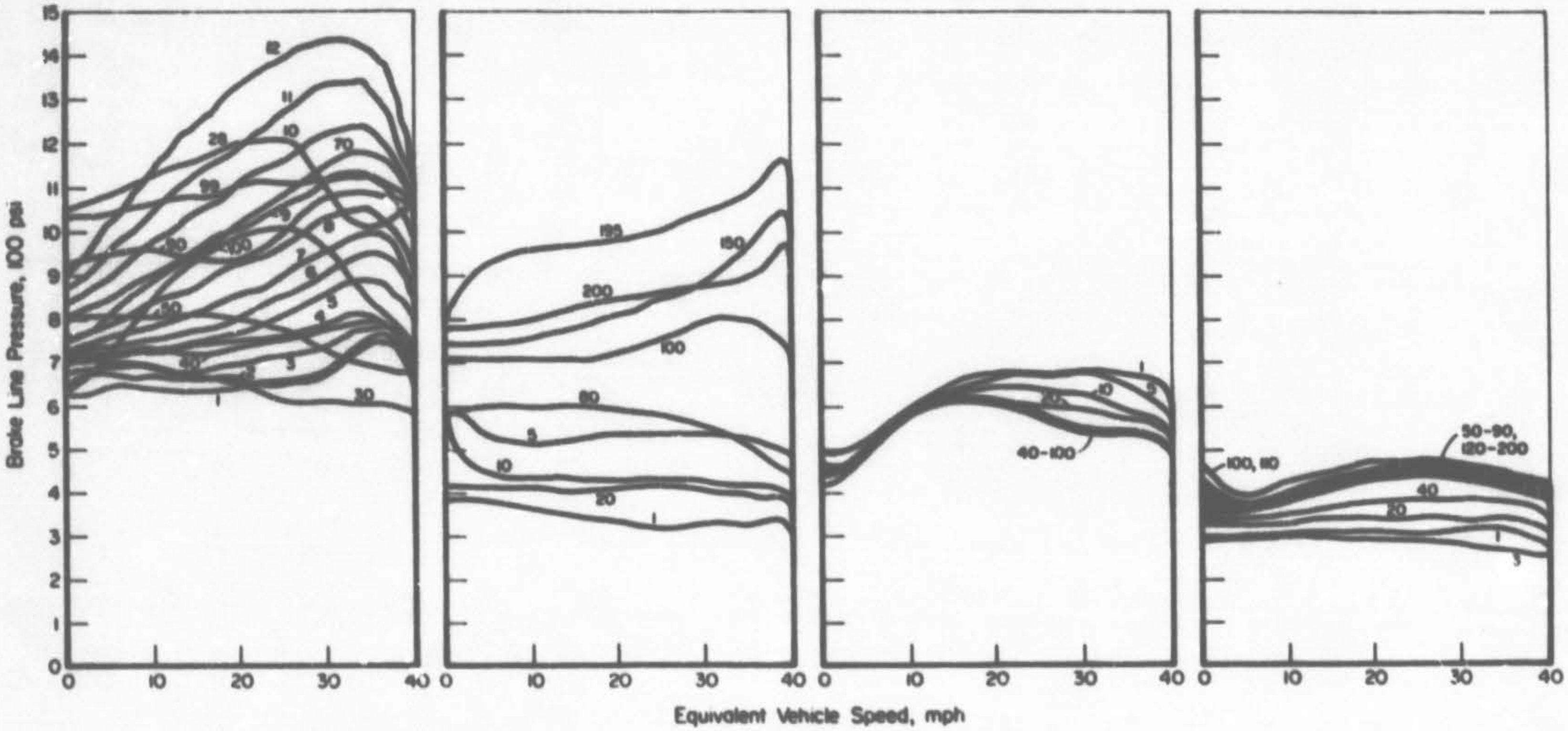
One example set of data follows which supports the claim that no acceptable asbestos-free friction materials have yet been developed for certain drum brakes. In this case a full brake dynamometer was used to test four different sets of drum brake linings on a 12-inch duo-servo drum brake with a 3-inch lining width. Identical procedures and matching test components were used, so the brake linings were the only known variables[11].

The linings tested have been coded, a condition for the availability of this test data. For simplicity of presentation, only the initial lining burnish test data is shown.

Figure 14a shows this data for Lining A, a NAO drum brake lining set. The test data is presented as brake line pressure versus equivalent vehicle speed. The brake line pressure relates to the amount of brake pedal effort exerted. All brake stops, after stop 3, were performed from the same initial brake drum temperature of 300 degrees F. All of the stops were from the same initial speed (40 mph) and controlled to provide an equivalent of 8 feet per second per second deceleration--a "normal braking" application. Note the wide range of pressures required to make the same stop. Even after 100 burnish applications, the required hydraulic pressures varied by a factor of two for adjacent stops. Also, the required brake pressures for this normal type of brake stop were almost to the limit for the power brake booster.

Brake lining A would be unacceptable for any OEM brake usage on this brake assembly. However, this lining formulation was released for production application on a different, smaller-sized drum brake. With a smaller brake and attendant thinner linings, lining A met all of the service requirements for an OEM brake lining. This demonstrates how the acceptability of a friction material is not just dependent upon the properties of the brake lining, but also depends on the specific choice of brake, vehicle, and use conditions.

Figure 14b shows performance curves for a NAO material B. Lining B was a candidate NAO material, but was not released for production. It used a different non-asbestos fiber system from that used in A. This lining provided, on average, higher brake effectiveness, but with a greater range of brake application pressures for the same test. Although not illustrated here, other test data for this lining show it to have an undesirable "morning sickness" with very high initial effectiveness for the first few cold stops. A lining like this on the rear drum brakes, used with a semimetallic front disc brake lining, would provide a vehicle brake system with a very strong tendency for rear wheel lockup (skidding) when cold.



a. NAO Lining A

b. NAO Lining B

c. Asbestos Production Lining C

d. Asbestos OEM Lining D

Note: Numbers on curves represent stop numbers in test.

FIGURE 14. COMPARISON OF DYNAMOMETER TEST RESULTS FOR FOUR DIFFERENT FRICTION MATERIALS, 300 F AFTER BURNISH, 12 x 3 DUO SERVO DRUM BRAKE (REF 11)

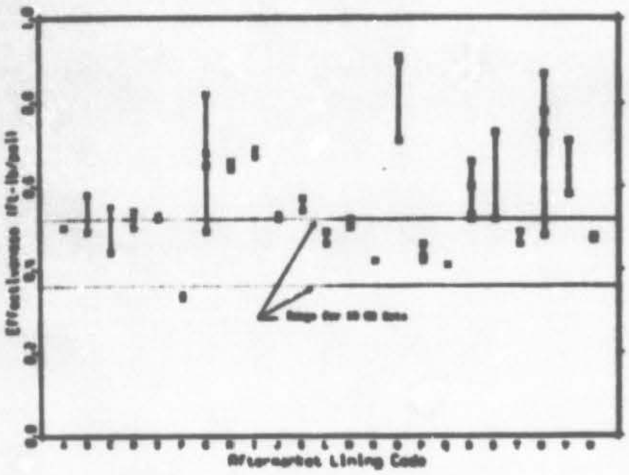
Figure 14c shows performance curves for a material C. Lining C, a "premium quality" aftermarket asbestos-based lining set, has been used for many years. Note the narrow band of brake line pressures for this burnish sequence. In particular, the stops from 40 through 100 were virtually identical. This consistency of brake effectiveness, although not guaranteed by the use of asbestos-based friction materials, is not yet available from any known NAO drum brake lining on this size of drum brake. Lining C had slightly higher (about 25 percent) lining wear rates than the two non-asbestos materials shown.

Figure 14d shows performance curves for asbestos material D. Lining D was the OEM released material for this brake system. It had the highest average effectiveness of the four linings and also the narrowest band of brake line pressures. In this case, the second 100 burnish-stop data was included to illustrate the consistency of performance that can be obtained from this brake. About 45 brake applications were required to obtain steady-state frictional behavior. After these, the test data were very repeatable, and the variation of effectiveness with speed was quite acceptable for a duo-servo drum brake.

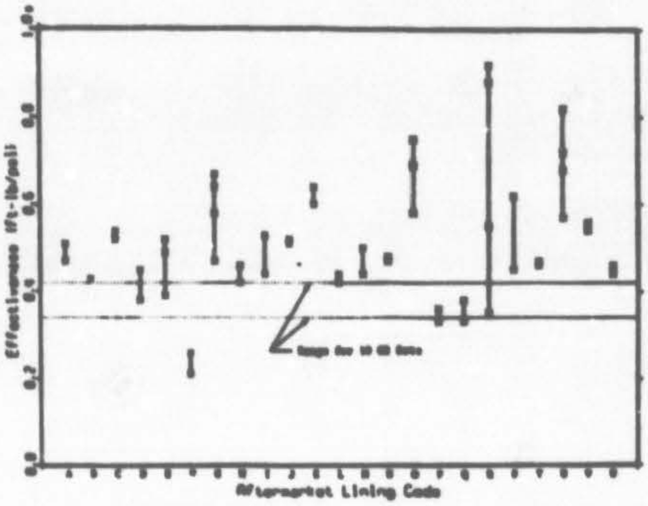
4.6.2 Vehicle Test Data

For a vehicle test study conducted by the National Highway and Traffic Safety Administration (NHTSA), the performance of aftermarket brake linings was compared to the performance of OEM linings[12]. These experiments were conducted using a compact size passenger car equipped with front disc brakes with semi-metallic pads and duo-servo drum brakes on the rear. Twenty-three different aftermarket rear drum linings were obtained by purchasing them from automotive service centers and automobile parts outlet stores. These materials were identified with a letter code of A through W.

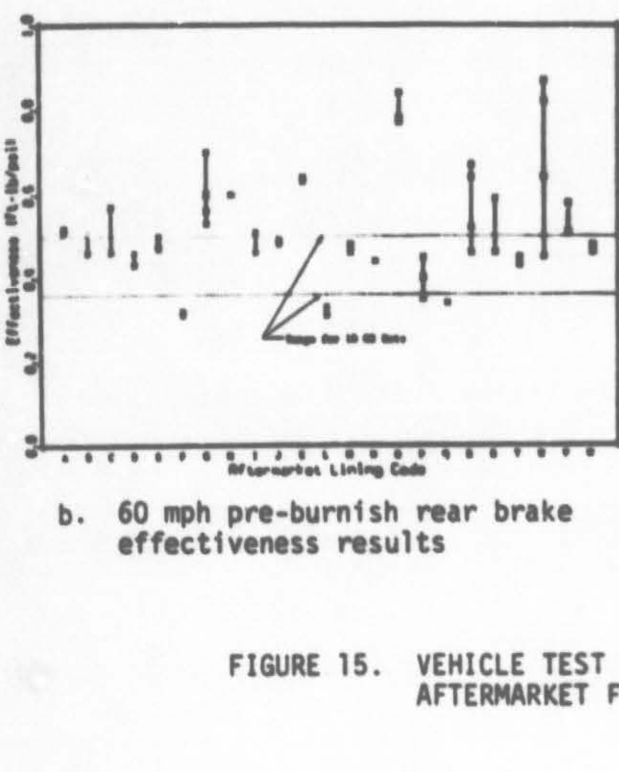
Experiments were conducted under conditions similar to those specified in FMVSS 105 (see Appendix A). To generate data representative of OEM lining performance, 10 sets of OEM-qualified linings were also obtained and tested to generate a comparison baseline.



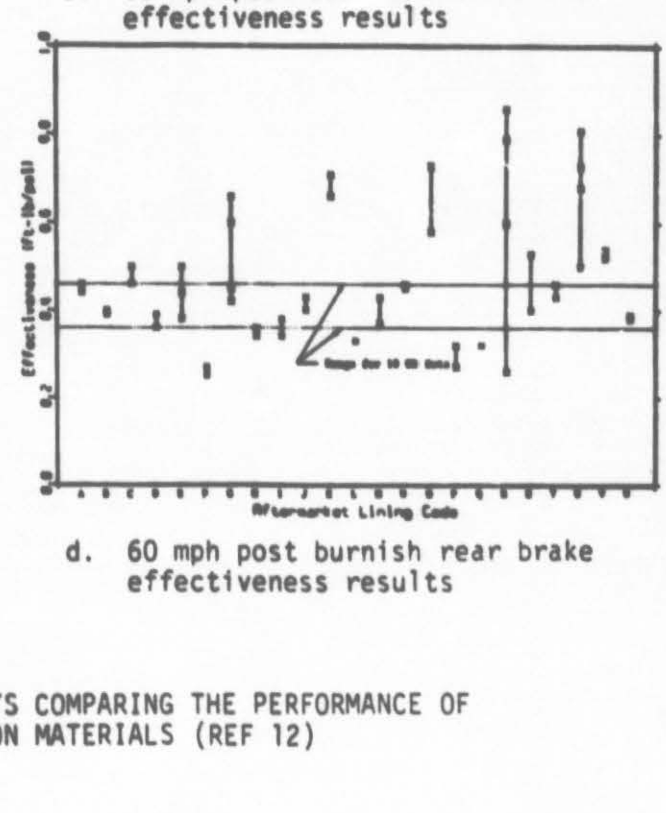
a. 30 mph pre-burnish rear brake effectiveness results



c. 30 mph post burnish rear brake effectiveness results



b. 60 mph pre-burnish rear brake effectiveness results



d. 60 mph post burnish rear brake effectiveness results

FIGURE 15. VEHICLE TEST RESULTS COMPARING THE PERFORMANCE OF AFTERMARKET FRICTION MATERIALS (REF 12)

Figure 15 shows the measured brake effectiveness for the various aftermarket linings under four different test conditions. At least two separate sets and as many as four separate sets of the same linings were tested; variations in performance are illustrated by the range in effectiveness exhibited among different sets of identical materials. Figures 15c and 15d indicate the wide range of effectiveness variability among the aftermarket materials. Lining material "R" exhibited the highest variability in effectiveness. This material was the only non-asbestos material tested of the 23 aftermarket materials tested. This data is consistent with the dynamometer test results presented in Figure 14. The remaining 22 test results also illustrate how wide variations in effectiveness can exist even for asbestos materials.

4.7 Issues of Consumer Acceptability of Non-Asbestos Materials

Consumer acceptability of non-asbestos friction materials, as with asbestos friction materials, will be affected by material wear performance and by the tendency to induce brake noise. Excessive brake wear could lead to sooty tire sidewalls, while brake noise continues to be an annoyance to many consumers.

Some brake materials used for front disc brakes have created a "dirty wheel syndrome" from wear debris(13). Also known as "dusting", this situation arises when fine, sooty wear debris is deposited on the outside wheel and the surfaces. This situation makes routine tire maintenance more undesirable since the black film is tenacious and usually makes the car owner's hands dirty. To prevent this situation, some car owners switch to aftermarket disc pads that are advertised as being "dusting resistant". Auto owners apparently assume that these materials are equally effective as braking materials as other materials more prone to dusting.

Aluminum "shields" are also available to shroud the disc and prevent debris from being deposited on the outer wheel surfaces. These shields are mounted between the disc and wheel of the brake and wheel assembly. Two adverse situations may arise from the use of such shrouds. First, the discs may operate at higher temperatures due to the decreased convection and radiation from the disc surface. Second, the wheel lug nuts may eventually loosen due to plastic deformation of the aluminum shroud in the vicinity of the lugs.

The "dirty wheel syndrome" has been reported more often by owners of German luxury automobiles, such as BMW and Mercedes, for many years. Owners of such vehicles tend to be more fastidious about the car's appearance than owners of other less expensive vehicles which utilize other materials. It is now becoming more of a problem on American and Japanese cars as more non-asbestos materials are utilized.

Nevertheless, the various techniques used by owners to eliminate the problem more clearly illustrate the public's viewpoint that vehicle brakes are largely unaffected by consumer neglect or tampering. Unless prohibited by legislation, OEM-qualified non-asbestos materials that exhibit excessive brake squeal or "dusting" could be replaced by materials provided by an unregulated aftermarket supplier, that need not meet any certification.

5. REVIEW OF VEHICLES AFFECTED BY PROPOSED BAN

5.1 Section Summary

The purpose of this section was to examine the various vehicle classes using friction materials and identify trends in braking systems in the various vehicle classses. The following observations were made:

- The overwhelming majority of American passenger cars are now designed with front disc brakes and rear drum brakes. There is not a significant trend toward wider use of 4-wheel disc brakes. American manufacturers are directing efforts toward developing suitable asbestos-free lining materials for rear automotive drum brakes.
- Because disc brakes maintain effectiveness at high braking speeds, 4-wheel disc brakes have been used in Europe on some high performance vehicles before asbestos became a concern. Now some European manufacturers use 4-wheel disc brakes and semi-metallic brake pads as a means of eliminating asbestos from passenger cars. Differences in consumer acceptance between Europe and the United States, specifically brake wear and brake noise, may restrict the use of 4-wheel disc systems in the United States.
- Trends in light truck braking systems follow those in passenger cars.
- Most medium trucks (American, European, and Japanese) use drum brakes on all four wheels. Acceptable qualified substitutes for current asbestos lining materials have not been found in many cases. These drum brake systems use segments, a thin lining material similar in geometry to automobile brake linings. However, the relatively severe braking requirements of this application prevent a simple retrofit of automobile materials to the medium truck market. A small percentage of medium trucks are now being produced with disc brakes and semi-metallic pads.
- Acceptable substitutes for asbestos materials have been found in some cases in the heavy truck segment. These

brake systems use thick molded brake blocks which are bolted or riveted to shoes. Some non-asbestos materials have been found to exhibit sufficient mechanical strength and frictional properties for this application.

5.2 Brake System Trends in Passenger Cars, Trucks, and Equipment

For this study, motor vehicles have been divided into three classes: passenger cars, on-highway trucks, and off-highway vehicles. Motorcycles, transit buses and trains, and aircraft have not been included.

The overwhelming majority of vehicles in the United States are, as expected, passenger cars (Table 8). The majority of the 1984 American passenger cars were fitted with a rear-drum and front disc brake system; 33 percent of 1984 imported automobiles were fitted with 4-wheel disc brake systems[14]. Medium and heavy trucks continue to use traditional drum brakes. Light trucks use front disc brakes with rear drum brakes.

5.2.1 Passenger Cars

Passenger cars are the largest single market for friction products in the U.S. As indicated previously, there were about 130 million registered passenger cars in 1984 in the United States.

Prior to 1965, almost all American passenger cars were equipped with 4-wheel drum brakes with asbestos linings. In 1965, some vehicles (Lincoln Continental and Chevrolet Corvette) were equipped with front disc brakes. Widespread use of front disc brakes across most product lines of American manufacturers began in the early 1970s.

There are a substantial number of vehicles that have drum brake systems designed for use with asbestos friction materials. In 1984, there were still 11.5 million cars in operation that were manufactured prior to 1970, and the majority of these presumably were fitted with 4-wheel drum brakes. Prior to 1982, the majority of automobiles with front-wheel disc brakes had been designed for use with asbestos brake pads. Since the mean life of passenger cars is now about 7.6 years[15], automobiles fitted with brakes designed for use with asbestos friction products will continue to be in operation for several more years. Vehicles manufactured in 1986

TABLE 8. NEW VEHICLE SALES AND VEHICLE REGISTRATION FOR 1984 (REF. 15)

	U.S. Calendar Year Sales (Millions)
<u>Passenger Cars</u>	10.4
Domestic	8.0
Imported	2.4
<u>On Highway Trucks</u>	4.1
Light	3.8
Medium	0.06
Heavy	0.20
<u>Off-Highway Vehicles</u>	
Farm equipment	0.17*
Construction equipment	0.05**

* 1986 estimate
** 1985 estimate

with asbestos friction materials can be expected to require aftermarket brake components for at least another 11 years.

Current American automobiles are almost exclusively designed with front wheel disc brakes. As shown in Table 9, American manufacturers do not appear to be embracing 4-wheel disc brakes as a means of changing the braking characteristics of automobiles. Currently, American manufacturers appear to be retaining rear wheel drum brakes. These brakes are attractive for the following reasons:

(1) Easier implementation of parking brake mechanism,
(2) Less susceptability to debris,
(3) Less susceptibility to corrosion,
(4) Less weight, and
(5) Less cost.

At the present time, there appears to be no distinct performance advantage under American driving speeds to rear wheel disc brakes other than reduced time required for maintenance. The use of rear disc brakes also simplifies the setting of front-to-rear braking balance.

The current trend among American automakers is to implement asbestos-free brake lining and brake pad materials in new major model changeovers. Brake systems on existing models are never routinely redesigned. New models, such as the Ford Taurus, are equipped with semi-metallic front disc brake pads and non-asbestos organic rear drum linings. Rather than redesign brake systems with 4-wheel disc brakes using semi-metallic pads, American automobile manufacturers have elected to retain rear drum brakes and direct development efforts toward new, non-asbestos rear drum linings. Qualification of non-asbestos materials through vehicle testing may take 2 years or longer, assuming a suitable material exists for a specific vehicle application. The redesign of a vehicle's rear brake system from drum brakes to disc brakes could take 5 to 7 years, with little guarantee of significantly improved performance.

5.2.2 On-Highway Trucks

On-highway trucks are generally classified with respect to gross vehicle weight class, i.e., by the vehicle curb weight plus cargo. Trucks can be considered single chassis vehicles or can be used in tractor-trailer

TABLE 9. LIST OF 1985 AMERICAN AUTOMOBILES EQUIPPED WITH 4-WHEEL DISC BRAKES (REFERENCE 16)

	Number of Units Sold With 4-Wheel Disc Brakes	Percentage of output
General Motors	164,301	3.6
Ford	46,608	2.7
Chrysler	0	0
American Motors Corporation	0	0
Volkswagen of America	82,797	100
Honda	0	0

combinations. Eight weight classes currently exist, although for the purposes of this study, the following classifications are used:

Classification	GVW Class	GVW Range (lbs)
Light	Group 1	6,000 and less
	Group 2	6,001 and 10,000
	Group 3	10,001 - 14,000
Medium	Group 4	14,001 - 16,000
	Group 5	16,001 - 19,500
	Group 6	19,501 - 26,000
Heavy	Group 7	26,001 - 33,000
	Group 8	33,001 - over

New truck registrations for 1984 indicate that light trucks make up approximately 94 percent of the total truck population, which reflects the popularity of small pick-up trucks and mini vans. In contrast, medium trucks account for about 1 percent of the population, while heavy trucks make up the remaining 5 percent(14).

The following sections outline current brake systems and trends in vehicle brake materials for the three classes of on-highway trucks.

5.2.2.1 Light Trucks. The "light truck" designation refers to both pick-up trucks and compact vans used in light hauling and passenger transport. About 3.9 million light trucks were sold in 1984 in the U.S. As of 1984, almost 31 million light trucks were registered in the United States.

Trends in light truck braking systems follow closely those of passenger cars. In 1984, more than 94 percent of light trucks manufactured in the United States were equipped with front wheel disc brakes. Ford and GM 1987 light trucks are using variable proportioning valves for rear brakes or anti-lock systems to improve braking under a wide range of truck loads. Calibration of a variable proportioning valve is affected by changes in rear brake lining material. In this respect, trucks brakes are following European passenger car trends in that design steps are being taken to ensure front wheel brake biasing.

Many light truck brakes manufactured in the United states are now using asbestos-free semimetallic materials in the front disc brakes and non-asbestos organic linings for the rear drum brakes. In 1986, the Ford Aerostar and Ranger models were fitted with all non-asbestos friction materials. The automotive industry is in the process of converting existing light truck models over to asbestos-free friction products.

Although new truck brake systems appear to be heading toward asbestos-free friction materials, a large population of older vehicles requiring aftermarket friction products still exists. Between 1970 and 1982, the median age of light trucks was 7.1 years(15).

5.2.2.2 Medium Trucks. The "medium truck" designation generally refers to single chassis trucks with a GVW of between 14,001 lbs and 26,000 lbs. These trucks usually are used as enclosed delivery trucks or open, flat-bed trucks. Manufacturers usually provide the engine, drive-train, cab, and chassis, which are custom modified to suit the customers' needs. Brake systems on this truck classification can be either hydraulic or air operated, depending upon customer selection and intended service. The majority of the systems are hydraulic due to lower initial costs associated with these systems. In 1982, there were 1.4 million medium trucks in service in the United States(14,15).

Current manufacturers and marketers of medium trucks in the United States are Ford, General Motors, Chrysler, Mack, and Mercedes-Benz, and others. These manufacturers typically purchase axle and brake assemblies from "foundation" axle and brake manufacturers and assemble them, along with the engine and chassis, into the finished truck. These brake systems are almost exclusively drum brakes on both the front and rear brakes. These brakes use strip linings similar to automotive drum brakes. However, due to the more severe braking conditions found in these trucks, qualified asbestos-free materials have not been found for some medium trucks.

Disc brakes for medium trucks are now under development, although the number now in service is very small(17). Some of the advantages cited for truck disc brakes are light weight and increased ease of maintenance. However, problems with excessive rotor and pad temperatures continue to limit their use in potentially severe braking conditions. European medium trucks produced by IVECO (Italy) and Saab-Scania (Sweden) are exclusively fitted with hydraulically actuated drum brakes[17,18,19].

5.2.2.3 Heavy Trucks. The "heavy truck" designation refers to either single-chassis trucks or segmented tractor-trailers having a GVWR of greater than 26,000 lbs. In general, the single chassis trucks have hydraulically-actuated brake systems, while the brakes of tractor-trailer combinations are generally air actuated.

Large truck brake systems are almost exclusively drum type, either of the leading-trailing type (Figure 3a) or the leading-leading type. For these severe braking requirements, thick block segments rather than thin strips of friction materials are bolted or riveted to shoes. Some success has been achieved in qualifying non-asbestos block materials for heavy truck applications. This success has been due in part to the ability to mold the non-asbestos materials into rigid blocks possessing sufficient mechanical strength.

The use of disc brakes in the heavy truck market has received some attention, but the overwhelming majority of the systems is still centered around the use of drum brakes. Because drum brakes still offer some performance advantages over disc brakes, a complete conversion to disc brakes in this vehicle market is not expected.

Qualification of non-asbestos materials for truck and trailer service is progressing through the combined efforts of foundation brake manufacturers, truck manufacturers, and friction product manufacturers. Most of the aftermarket friction product manufacturers do not possess the facilities to evaluate the performance of their products under vehicle service conditions.

5.2.3 Off-Highway Trucks and Equipment

Farm equipment and construction equipment have braking needs different from those of on-highway trucks. Braking speeds will be lower and required brake torques will be higher.

Examples of off-highway equipment include road scrapers, road graders, excavators, haulers, cranes, mobile drilling rigs, and other large pieces of equipment. Farm equipment can range from small tractors to large harvesting combines.

Qualification of friction products for these applications is usually the responsibility of the foundation brake manufacturer and the equipment manufacturer since no Federal braking requirements exist. Materials found to perform satisfactorily through years of customer and manufacturers' experience are rarely changed since the usage conditions and equipment change only slightly.

The development of qualified asbestos replacements for this market segment may be difficult due to the extended time required for development, coupled with the relatively small market represented by the farm and construction equipment industry.

5.3 Current European and Japanese Experience in Brake Design and Friction Material Selection (Automobiles and Light Trucks)

The bulk of the European import automobile and truck market is comprised of vehicles manufactured in Germany, Great Britain, France, Sweden, and Italy. As indicated previously, most of the recent imported European automobiles are fitted with front wheel disc brakes which use semimetallic asbestos-free friction pads. There is a strong trend among European automakers to use 4-wheel disc brakes, along with semimetallic materials. Table 10 lists the European automakers and the percentage of their product lines that are equipped with 4-wheel disc brakes. Although the percentage of new European 4-wheel disc brake imports is high (80 percent), the total number of units imported is small compared with United States automobile production.

European drivers have different preferences with respect to brake performance than do American drivers. In general, Europeans are more tolerant of brake squeal and brake wear than are American drivers, and materials judged acceptable from a standpoint of stopping performance alone may not be acceptable to the American public. In addition, the European safety standards are different from those in the United States but are difficult to compare directly. Generally, the ECE/EEC regulations allow lower levels of braking efficiency than do the United States regulations, but they do require calculations to show that the "design intent" brake balance is front bias, i.e., front wheels lock first. The emphasis

TABLE 10. LIST OF 1984 EUROPEAN-MANUFACTURED AUTOMOBILES EQUIPPED WITH 4-WHEEL DISC BRAKES (REF. 14)

	Number of Units Sold in the U.S.	Percentage With 4-Wheel Disc Brakes
Germany		
Mercedes-Benz	58,017	100
Volkswagen	64,405	100
BMW	64,525	58.6
Audi	54,590	15
Porsche	14,708	100
Great Britain		
Jaguar	18,044	100
France		
Renault	10,277	0
Peugeot	14,792	100
Italy		
Alfa Romeo	3,399	100
Sweden		
Volvo	96,422	100
Saab	25,146	100
TOTAL	424,325	83

of front biasing makes 4-wheel disc brakes attractive because the effectiveness of disc brakes are less affected by slight changes in friction material performance. Automakers can help ensure that the brakes are front biased in spite of unforseen friction product behavior by using proportioning valves to force the front discs to handle most of the vehicle braking.

Virtually all of the Japanese automobiles imported to the United States are fitted with front disc brakes, although some models are also equipped with 4-wheel disc brakes. Table 11 lists the percentages of Japanese vehicles equipped with 4-wheel disc brakes. In 1984, only 20 percent of the 1 million units sold in the United States were so equipped.

The eventual adoption of FMVSS 135 and the failure to qualify rear automotive brake drum linings exhibiting consistent levels of friction over a wide range of performance conditions may affect the design philosophy of American and Japanese automobile engineers. Forced to ensure front bias in the system, automakers may eventually move to using less-effective disc brakes on the rear axle and increasing the front-to-rear braking ratio to ensure consistent system performance, if proven rear drum lining materials are not found.

TABLE 11. LIST OF 1984 JAPANESE AUTOMOBILES SOLD IN THE UNITED STATES EQUIPPED WITH 4-WHEEL DISC BRAKES (REF 10)

	Number of Units Sold	Percentage With 4-Wheel Disc Brakes
JAPAN		
Honda	374,819	17.9
Nissan	372,633	32.7
Toyota	306,900	24.9
Subaru	148,880	0
Mitsubishi	39,104	>0
Isuzu	17,233	>0
Mazda	128,197	0
TOTAL	1,387,766	>20

6.0 SUMMARY OF INDUSTRY RESPONSES TO PROPOSED BAN

6.1 Section Summary

Various concerns representing automobile manufacturers, truck and equipment manufacturers, friction product producers, and environmental groups responded with written comments to the Environmental Protection Agency's proposal outlined in the Federal Register. Table 12 lists the respondents.

In general, respondents commented on numerous facets of the proposal, but the comments most pertinent to this study were those dealing with issues of brake performance, application availability, and feasibility of the proposed phase-down schedule. The comments of respondents have been categorized in the following sections with respect to the issues addressed.

Table 13 summarizes in a very general sense the responses of the various industries and groups to the main features of the proposed EPA ban.

6.2 Concerns of Respondents to Issues of Brake Performance

The comments of the respondents to this issue are summarized in Appendix D. The automobile and truck manufacturers were consistent in their opposition to the proposed ban on asbestos in aftermarket friction products. These manufacturers contend that vehicle safety may be compromised if unproven friction products are used in place of vehicle-tested products containing asbestos. One truck manufacturer (Navistar) claims that brake and friction product qualification can take up to 48 months, so the time and cost of re-qualifying materials for other aftermarket products would be prohibitive.

Some manufacturers question the long-term performance of some asbestos-free materials and subsequently feel that further development will be necessary before a phase-out can be feasible. Ford Motor Company indicated that friction products must be qualified under long term conditions more stringent than federal motor vehicle safety standards in order to determine the sensitivity of materials to "hot-spotting" and "morning sickness". Rockwell International inferred that current non-asbestos

TABLE 12. LIST OF RESPONDENTS TO FEDERAL REGISTER NOTICE REGARDING PROPOSED EPA ACTION

Automobile Manufacturers

Japanese Automakers

Toyota Technical Center, U.S.A., Inc.
Subaru of America, Inc.
American Honda Motor Company, Inc.
Mitsubishi Motors Corporation
Nissan Research and Development, Inc.

American Automakers

Chrysler Corporation
General Motors Corporation
Ford Motor Company
American Motors Corporation

European Automakers

Volkswagen of America
Mercedes-Benz of North America, Inc.
Austin Rover Group Limited

Trade Associations

Automobile Importers of America, Inc.
National Automobile Dealers Association
Motor Vehicle Manufacturers Association

Environmental Lobbyists

National Resources Defense Council, Inc.

Truck and Equipment Manufacturers

Foundation Brake and Axle Manufacturers

Rockwell International

Truck Frame and Chassis Builders

Navistar International Corporation
Freightliner Corporation

Farm Equipment

John Deere and Company

Friction Product Manufacturers

OEM Compounders

Allied/Bendix Corporation
Abex Corporation

Aftermarket Suppliers

Wagner
Scan-Pac
Original Quality, Inc.

Trade Association

Friction Materials Standards Inst.

Fiber Suppliers

DuPont

TABLE 13. SUMMARY OF RESPONDENTS' COMMENTS TO PROPOSED EPA PLAN

	Brake Performance	Substitute Availability	Feasibility of Proposed Phase Down
Automobile Manufacturers	• aftermarket for older vehicles should be exempt	• materials for front disc brakes available • materials for rear drum brakes not qualified sufficiently	• phase-down plan opposed • 5-year lead time prior to ban favored
Truck and Equipment Manufacturer	• aftermarket for older vehicles should be exempt	• materials for heavy on-road and off-road vehicles not available or qualified as yet	• phase-down plan opposed • 5-year lead time prior to ban favored
Friction Product Manufacturers	• performance of some materials still needs qualification (Allied/Bendix) • performance of substitutes as good or better than asbestos (Scan-Pac)	• many vehicle applications have no qualified materials (Allied/Bendix) • substitutes available for all applications (Scan-Pac)	• many substitutes will be available within 5-years (Allied/Bendix) • substitutes now available (Scan-Pac)
Environmental Lobbyists	--	• substitutes available for all applications	• immediate ban on current and aftermarket asbestos friction materials

materials designated for off-highway heavy-duty applications give unacceptable performance and durability.

Friction product manufacturers gave mixed reports concerning product performance. Allied/Bendix indicated that development work was still progressing, and substitute formulations need to be evaluated using vehicle tests and dynamometer tests. Scan-Pac, on the other hand, claimed to have products available for all heavy-duty vehicle applications, although no in-house inertia dynamometer or vehicle test facilities are available at Scan-Pac's facility for qualification of materials.

6.3 Concern of Respondents to Issues of Friction Material Availability

The comments of the respondents to this issue are summarized in Appendix C. U. S. and Japanese automobile manufacturers indicate that non-asbestos front disc brake pads are now being used extensively on new car models. Chrysler indicated that all but one vehicle manufactured by Chrysler is fitted with semi-metallic front brake pads, while General Motors acknowledged that for front disc brakes, asbestos-free replacement materials are now available for new model cars. Asbestos-free rear drum brake materials are still not available for automotive applications.

Volkswagen indicated that in model year 1987 all products will be fitted with non-asbestos linings, while Daimler-Benz indicated that new 300 series models will be fitted with asbestos-free friction materials. Daimler-Benz did indicate that brake systems of other vehicles in their product line are undergoing lengthy and extensive redesign and requalification to be fitted with non-asbestos materials.

Since most heavy duty truck and equipment brakes use drum brakes, the concerns of truck and equipment manufacturers were different from those of the automobile manufacturers. Since truck life is considerably longer than automobile life, aftermarket availability for older vehicles remains a strong concern. Freightliner and Rockwell indicated that friction product suppliers have been unable to provide qualified non-asbestos linings for heavy-duty on-highway and off-highway applications. John Deere indicated that replacement materials have not been qualified for use in tractor transmission clutches and axle brakes.

Friction product manufacturers gave mixed reports concerning the availability of asbestos-free materials for the various applications. Allied/ Bendix indicated that they had been successful in developing asbestos-free products for some applications, although many vehicle applications currently remain without qualified asbestos-free materials. Scan-Pac and DuPont both indicated that substitute materials are available for all applications, although Scan-Pac has concentrated on providing materials for aftermarket heavy vehicle applications. However, both Scan-Pac and DuPont lack the facilities to conduct vehicle or dynamometer tests required for FMVSS certification.

6.4 Concerns of Respondents to Feasibility of the Proposed Phase-Down Schedule

The comments of the respondents to this issue are summarized in Appendix D. The automobile industry, both domestic manufacturer and importers, voiced unanimous concern over the proposed timetable for asbestos phase-out. The following were major points made by this industry:

(1) The years 1981, 1982, and 1983 were years of severe recession in the automobile industry. Therefore asbestos-usage quotas based on asbestos usage during these years are excessively restrictive.

(2) The proposed rating is unfair to auto importers, who voluntarily restricted imports during 1981, 1982, and 1983.

(3) Option 1, which allows a five-year lead time to develop and qualify new asbestos-free materials, is preferable than the proposed staggered phase-down effort.

(4) If FMVSS 135 is adopted, more lead time may be required, depending upon exact provisions of FMVSS 135.

Truck and equipment manufacturers, whose products rely upon drum brake materials, were opposed to the proposed immediate reduction in allowable asbestos in friction materials. Navistar, Freightliner, and Wagner supported a plan in which most asbestos use was banned after a 5-year lead time. Modifications of this provision would allow the use of asbestos in materials for which no replacement material was qualified. John Deere requested an exemption for all materials used inside a machine housing, such as clutches and sealed axle brake units used on John Deere tractors.

The friction product manufacturers gave mixed reports concerning the proposed phase-down schedule. Allied/Bendix indicated that reliable alternatives for original equipment materials will be available within 5 years. DuPont and Scan-Pac, on the other hand, indicated that acceptable substitute materials now exist. Both companies lack the facilities to qualify materials and systems under Federal safety standards.

The National Resources Defense Council (NRDC) supports an immediate ban on all asbestos in friction products, both new and aftermarket. They contend that viable substitutes are available today.

7. REFERENCES

(1) Newcomb, T. P., and Spurr, R. T., Braking of Road Vehicles, Robert Bentley, Inc., Cambridge, Massachusetts 1969.

(2) Starks, H. J., "Loss of Directional Control in Accidents Involving Commercial Vehicles", 1963 Symposium on Control of Vehicles (Inst. Mech. Engrs., London) 8.

(3) Anderson, A., "Wear of Brake Materials", from Wear Control Handbook, M. B. Peterson, W. A. Winer, Editors, ASME, New York, New York.

(4) Preston, J. D., and Forthofer, R. J., "Correlation of Vehicle, Dynamometer, and Other Laboratory Tests for Brake Friction Materials", SAE Paper No. 710250, Warrendale, Pennsylvania.

(5) Tsang, P., Jacko, M., and Rhee, K., "Comparison of Chase and Inertial Brake Dynamometer Testing of Automotive Friction Materials", 1985 Wear of Materials Conference, ASME, 1985, New York.

(6) Burkman, A. J., and Highley, F. H., "Laboratory Evaluation of Brake Lining Materials", Paper NO. 670510, Warrendale, Pennsylvania.

(7) Preston, J. D., "Inertia Dynamometer Evaluation of Brake Lining Materials", SAE Paper No. 730192, Warrendale, Pennsylvania.

(8) Steis, D. E., "Inertia Brake Dynamometer Testing Techniques for FMVSS 121", SAE Paper No. 751010, Warrendale, Pennsylvania.

(9) Anderson, A., Ford Motor Company (personal communication).

(10) "Substitution Analysis for Asbestos Brake Linings for On-Road Vehicles", prepared by ICF, Inc. for Ms. Amy Moll, Environmental Protection Agency, Washington, D.C.

(11) Data provided by A. Anderson, Ford Motor Company

(12) Flick, M. A., Radlinski, R. W., and Kirkbride, R. L., "The Effect of Aftermarket Linings on Braking Efficiency", SAE paper 870267, February 1987, Warrendale, Pennsylvania.

(13) Fobian, J., AAA (American Automobile Association) (personal communication).

(14) Ward's Automotive Yearbook, 1985, Ward's Communication's, Detroit, Michigan.

(15) Motor Vehicle Manufacturers Associate (MVMA) Motor Vehicle Fact and Figures, 1985.

(16) Automotive News, 1986 Market Data Book Issue, April 30, 1986.

(17) Aoki, K., "Japanese Track Brake Philosophy", Worldwide Braking Trends: Medium and Heavy Duty Trucks, SAE 1984, Warrendale, Pennsylvania.

(18) Thoms, E., "European Brake Philosophy", Worldwide Braking Trends: Medium and Heavy Duty Trucks, SAE 1984, Warrendale, Pennsylvania.

(19) RothVegel, K., and Denzler, U., "European Brake Philosophies for Commercial Vehicles in the Range From 6 to 16 Tons FVS", Worldwide Braking Trends: Medium and Heavy Duty Trucks, SAE 1984, Warrendale, Pennsylvania.

AIA COMPANIES

ALFA ROMEO

BMW

FIAT

HONDA

HYUNDAI

ISUZU

JAGUAR

LOTUS

MAZDA

MITSUBISHI

NISSAN

PEUGEOT

PORSCHE

RENAULT

ROLLS-ROYCE

SAAB-SCANIA

SUBARU

SUZUKI

TOYOTA

VOLVO

OPTS Docket # 62036 Asbestos Ban
R/P E ______ File

AUTOMOBILE IMPORTERS OF AMERICA, INC.

1725 JEFFERSON DAVIS HIGHWAY, SUITE 1002 • ARLINGTON, VA 22202 • (703) 979-5550 • RAPIFAX (703) 979-1535

86 JUN 27 P 4:22

62036
E206

June 27, 1986

Hearing Clerk
Office of Toxic Substances (TS-793)
Environmental Protection Agency
401 M Street, S.W.
Washington, D.C. 20460

To Whom It May Concern:

Pursuant to 40 CFR §750.6, the Automobile Importers of America, Inc. (AIA) hereby requests to testify at hearings on the Proposed Mining and Importation Restrictions of Asbestos and Asbestos Products which are scheduled to begin on or about July 15, 1986.

AIA is extremely concerned over the proposed permit program and limitations on asbestos content as applied to automobiles and other motor vehicles.

AIA's oral presentation will focus on the reasons the proposed regulatory scheme is unreasonable and highly discriminatory toward imported vehicles. AIA will also discuss the proposals it has to remedy the failings in the proposed regulatory scheme, assuming for the sake of argument, that there is a technical basis for any such program.

The oral presentation should take no longer than 30 minutes, not including responses to questions that the Agency may want to ask.

Due to conflicts caused by AIA Board of Directors meetings during the week of July 14, I hereby request that AIA be allowed to testify during the week of July 21, 1986. If AIA is allowed to testify during this week, I will testify on behalf of the organization. If it is not possible to schedule this testimony during the week of July 21, AIA hereby requests to testify on July 16, 1986. No other day during this week is possible due to AIA's Board of Directors meeting and other commitments by AIA's outside counsel. If AIA is allowed to

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testify on July 16, Richard A. Penna, a partner in the law firm Schnader, Harrison, Segal & Lewis will testify on AIA's behalf. Mr. Penna was actively involved in the preparation of AIA's comments and can discuss each of the points raised in AIA's comments.

Thank you for your consideration of this request.

Sincerely yours,

George C. Nield

George C. Nield
President

cc: John Rigby, Esquire

USEPA to Autombile Importers
OPTS Docket # 62036 Asbestos Ban
M/C E 20de File

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

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AUG 27 1986

OFFICE OF
PESTICIDES AND TOXIC SUBSTANCES

Dear Asbestos Hearing Participant:

On July 30, 1986, the Asbestos Hearing Panel addressed a number of written questions to expert witnesses of the Asbestos Information Association/North America and the Asbestos Institute (hereafter collectively referred to as "AIA"). On August 21, 1986, the Hearing Panel received AIA's response to those questions. The Hearing Panel has reviewed the AIA response and determined that the record is now sufficiently complete to close the legislative hearing phase of this proceeding.

Under the Environmental Protection Agency's (EPA's) procedural rules, any participant may submit a written request for cross-examination after the close of the legislative hearing (40 CFR 750.8(a)). Requests are to be received by EPA within one week after a full transcript of the legislative hearing becomes available. The transcript and the AIA response to the Panel's written questions are now available. To assure an adequate opportunity for the preparation and submission of any cross-examination requests, participants will be given until September 15, 1986, to make those submissions. Please refer to my letter of August 1, 1986, to all hearing participants for information on the submission of cross-examination requests.

Hearing participants may still submit corrections to the transcript of their testimony to the EPA. EPA will include a complete set of corrections in the record after receiving these corrections from hearing participants and after noting corrections to any Agency statements included in the transcript.

Sincerely,

David L. Dull, Chair
Asbestos Hearing Panel

USEPA to Autombile Importers
OPTS Docket # 62036 Asbestos Ban
M/C E 20 C File

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

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AUG 1, 1986

OFFICE OF
PESTICIDES AND TOXIC SUBSTANCES

Dear Asbestos Hearing Participant:

Thank you for your participation in the legislative hearing on the Environmental Protection Agency's (EPA's) proposed rule to ban certain asbestos products and phase out others. (Docket No. OPTS 62036 (Asbestos; Proposed Mining and Import Restrictions and Proposed Manufacturing, Importation, and Processing Prohibitions, 51 FR 3738, et seq.))

This letter informs you that as a participant you may submit a written request for cross-examination. This request is due to EPA within one week after a full transcript of the legislative hearing becomes available (40 C.F.R. §750.8(a)(1985). Oral testimony at the legislative hearing ended on July 25, 1986. EPA, however, has written to one of the participants in that hearing with questions addressed to that participant's expert witnesses, who submitted comments on behalf of that participant, but were not made available at the legislative hearing. A copy of that letter is enclosed. EPA intends to hold open the legislative hearing until the Agency receives a response to its request. Therefore, the full transcript of the legislative hearing will not be available for a number of days.

To assist in preparing your cross-examination request, should you choose to submit one, an explanation of the cross-examination right under section 6(c) of the Toxic Substances Control Act (TSCA), 15 U.S.C. §2605(c), is in order. Section 6(c)(3)(A) provides a right to cross-examination during informal rulemaking hearings if EPA determines that there are disputed issues of material fact it is necessary to resolve and that such cross-examination is appropriate and required for a full and true disclosure with respect to such issues.

EPA's procedural rules require that all requests for cross-examination must be justified in light of the standards set forth in section 6(c) of TSCA (40 C.F.R §750.8). In particular, persons requesting cross-examination must state clearly why the questions at issue are factual rather than of an analytical or policy nature and why cross-examination, rather than alternative means, can be expected to result in full and true disclosure resolving the facts involved. The panel will also need an estimate of the time required for cross-examination.

It is of particular importance, therefore, that all persons requesting cross-examination specify in writing the precise questions they wish to ask and specifically refer to the appropriate portions of the rulemaking record. This will enable EPA to determine whether there is a disputed issue of material fact and whether cross-examination is necessary and appropriate. It is the Agency's intention to limit cross-examination to the written questions submitted in advance with the expectation that these written questions would be specific enough to avoid the need for extensive follow up. Any follow up questions that are needed would be allowed only within the scope of the written questions.

EPA believes, furthermore, that the submission of written questions will result in a more efficient and focused hearing. For example, written questions will facilitate the identification of witnesses who can respond adequately, alert witnesses to the documents they will need during questioning and allow witnesses to prepare adequately for questions requiring a complicated response. EPA may suggest a panel of witnesses if more than one person would be appropriate to respond to a question or group of questions.

Should you have any questions regarding the procedures in this letter, please contact us.

Sincerely,

David L. Dull
Chair, Asbestos Hearing Panel

Enclosure

USEPA to Autombile Importers
OPTS Docket # 62036 Asbestos Ban
M/C E 20 d File

62036
E20d

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

AUG 15

AUG 15 1986

OFFICE OF
PESTICIDES AND TOXIC SUBSTANCES

Dear Asbestos Hearing Participant:

The transcript of the oral testimony at the legislative hearing on the Environmental Protection Agency's (EPA) proposed rule to ban certain asbestos products and phase out others is now available in the docket office, Room NE-G004. If you wish, you may review the transcript and submit corrections.

As noted in my letter of August 1, 1986, the Hearing Panel will notify hearing participants by letter of the date of the official closing of the legislative hearing. The legislative hearing will close after the panel receives the information requested in its letter of July 30, 1986, to counsel for the Asbestos Information Association/North America (AIA) and the Asbestos Institute (AI). We currently anticipate the deadline for submission of cross-examination requests to be on or about September 4, 1986.

Sincerely,

David L. Dull, Chair
Asbestos Hearing Panel

Project: ______

Name of ICF Caller: Mike Geschwind

62036

Organization Contacted: Battelle Columbus

Location: Columbus, OH

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B6 - 376

Name of Person Contacted: Scott Barber

Position of Person Contacted: Tribology Research and Development

62036
B6 ____ file

Phone Number: 614-424-4779

Date/Time of Contact: 6/26/87

Questions/Responses:

RIA 376

Arne Anderson, one of the panel members who is At Ford Motor Company

RIA 376
LOG 2240

Chokthe

When driving can have 50/50 split w/ front + back brakes but ~~must be equal~~

Companies have had difficulty getting non-asbestos rear drum brakes which have friction acting same when cold than when hot. So they shift braking to front w/ semi-metallic.

The reason is in autos can keep shifting wt. to the front.

Can't keep shifting at higher weight vehicles such as medium weight

Rear Brakes must share the wt. a little bit more for med vehicle (vehicle downsizing can affect this). There is only so much you can shift to the front. Because temp gets too expensive in front.

Riveting vs. Bonding

It is true about riveting vs. bonding. The way of making the brakes linings in cars and Ht/med vehicles are the same.

Problem w/ NAO in rear

Semimetallic - cold = don't work as well so NAO took load in pack - then can will skid

New law may say if brakes lock up - the front must lock ~~front~~ because then you'll lose only steering whereas when back lock lose control

2240

Brake blocks 3/4 inch thick molded blocks can mold them and they can't unbolt very easily However for med. trucks layer is 1/4" thick So not much structural integrity strength so it doesn't

*To be maintained in permanent file.

ICF INCORPORATED

For autos they glue them on. Can't bond for medium
medium trucks since they won't last as long
For medium trucks more braking load
to get to stop so shear forces at the interface
w/ the bond) + braking pressure too high so would
like to rivet them to the pad instead
of glueing as they do with light vehicles.
Therefore light trucks fell into a nebulous
borderline.

In the past haven't gotten bond strength
up yet and haven't had luck
riveting them on (medium trucks) for
non-asbestos materials. They may soon
get good bond or secure rivet hold.

Saab, British and German cars still use 4 wheel
drum brakes on medium-sized vehicles

To his knowledge - medium trucks
have almost all 4 wheel drum brakes
so can't transfer wt. to front.

For Worldwide Trends in Truck Braking
SAE paper.

Project:

Name of ICF Caller:

Organization Contacted:

Location:

Name of Person Contacted:

Position of Person Contacted:

Phone Number:

Date/Time of Contact:

Questions/Responses:

Fade also not considered in other reports

Brake ~~F~~Fade - pumping brakes going down mtn.

friction characteristics

Not

~~This~~ is inaccurate ~~accurate~~, immediately ~~they~~ shows

up in severe braking conditions.

Can recover w/ time. ~~[illegible]~~

---

*To be maintained in permanent file.

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ICF INCORPORATED

9300 Lee Highway
Fairfax, Virginia
22031-1207

703/934-3000

2283

62036

ICF INCORPORATED

RIA 377
406
435

LOG 2283

May 2, 1988 B6-377

MEMORANDUM

TO : The Record

FROM : Michael Geschwind
Peter Tzanetos
Frank Arnold

RIA 377
406
435

SUBJECT : Missing Telephone Logs for the Asbestos RIA

This memorandum discusses the nine missing telephone logs mentioned in the April 26th memorandum to Christine Augustyniak and Joni Repasch. After analyzing the RIA, we have concluded the following non-CBI information was based on each telephone log:

1. Ertel Engineering (Reference #175)

Ertel Engineering discontinued the use of asbestos in the production of paper filters in 1985.

2. Marley Cooling Tower Company (Reference #180)

Marley Cooling Tower Company no longer manufactures asbestos fill for cooling towers in the United States. Several products available as substitutes for asbestos cooling tower fill have limited application due to specific disadvantages. Wood is not an adequate substitute because it is not economically feasible to manufacture it in the sheet forms required for cooling tower fill. Portland cement reinforced with mineral and cellulose fibers is presently under development as a substitute, but currently is only available in limited shapes and at high cost.

3. Allied Automotive (Reference #373, 404, 434, and 447)

In light and medium vehicles, the lining segments of drum brakes are usually a third of an inch thick or less and are called drum brake linings; however, in heavy vehicles such as heavy trucks and off-road vehicles, the drum brake linings are at least three-quarters of an inch thick and are called brake blocks instead of drum brake linings.

Brake linings are either bonded (glued) or riveted onto the brake shoe. Bonded brake linings have greater frictional surface area than riveted linings, but riveted linings are quieter.

Allied Automotive has two plants, one in Cleveland, TN and the other in Green Island, NY, both of which manufacture asbestos and non-asbestos drum brake linings. Allied Automotive also produces semi-metallic drum brake

Rec'd 5/2/88

linings.

Asbestos drum brake linings account for approximately 90-95 percent of OEM sales and almost 100 percent of aftermarket sales.

Allied Automotive estimates that 18 percent of its 1986 drum brake lining production will be non-asbestos. Producers of brake linings are highly averse to the risk that could be associated with new substitutes. The risk is magnified when a major brake system redesign is required for a substitute lining.

Semi-metallic disc brakes are already used on the front wheels of 85 percent of all new light/medium vehicles. Furthermore, some luxury import cars are now equipped with four semi-metallic disc brakes.

Replacement of asbestos-based drum brake linings in the aftermarket is much more difficult than in the original equipment maarket (OEM). Brake systems designed for asbestos lining should continue to use asbestos linings. Substitute lining formulations that are designed for the OEM, when used to replace worn asbestos linings, do not perform as well as asbestos and could jeopardize brake safety.

Disc brake pads are either bonded (glued) or riveted onto the steel plate in a disc brake. Bonded disc brake pads have greater frictional surface area than riveted pads, but riveted pads are quieter.

Semi-metallic disc brake pads are molded products containing chopped steel wool, sponge iron, graphite powder, fillers, and resins. Some semi-metallic pads contain a very thin asbestos-containing backing, or underlayer, between the steel plate and the pad. Other semi-metallic pads have no underlayer or have one made of a non-asbestos material. The underlayer acts as a thermal barrier between the pad and plate, and helps to bond the pad to the plate. Producers of disc brake pads generally do not consider semi-metallic pads with the asbestos underlayer to be asbestos pads because the lining itself contains no asbestos and the underlayer is only a very small percentage of the total content of the pad. Substitutes for the thin asbestos underlayer in some semi-metallic pads include either no underlayer or a chopped fiberglass or Kevlar(R) underlayer, depending on the application. The substitutes for the asbestos underlayer perform just as well as the asbestos underlayer.

Semi-metallic disc brake pads perform better at higher temperatures than asbestos-based disc brake pads and have a longer service life. In general, at lower temperatures asbestos-based pads perform better than semi-metallics, and are quieter. Front-wheel drive vehicles, which have greater brake load in the front (and thus generate more brake heat in the front) than real-wheel drive vehicles, exclusively use semi-metallic disc brakes in the front.

Currently, asbestos probably holds no more than 15 percent of the OEM for disc brake pads for light/medium vehicles, and the balance (85 percent) is nearly all semi-metallics. By 1990, asbestos will be almost completely replaced in the disc brake pad OEM, given the trend towards 100 percent front-wheel drive light/medium vehicles.

Replacement of asbestos pads in the aftermarket is much more difficult than in the OEM. Brakes systems designed for asbestos pads should continue to use asbestos. Semi-metallic pads which were designed for the OEM, when used to replace worn asbestos pads, do not perform as well as asbestos, and could jeopardize brake safety.

Three primary reasons for little or no development of substitutes engineered for aftermarket brake systems that were designed for asbestos:

- developing adequate substitutes for a system designed specifically for asbestos involves considerable technical difficulty;
- no federal safety and performance standards exist for brakes for the aftermarket; and
- producing and testing substitute formulations is very expensive.

Disc brake pads (asbestos and non-asbestos) for heavy vehicles are a small and relatively new market. Although disc brake pads were a small percentage of heavy vehicle brakes in the past, these systems are increasingly common for heavy vehicles. Except for the larger size, disc brake pads for heavy vehicles are similar to those described for light/medium vehicles. To date, disc brake pads for heavy vehicles are only used on the front wheels of certain intermediate-sized trucks, 12,000-22,000 lbs. per axle. They can never be used for the heaviest trucks.

Although non-asbestos semi-metallic pads have nearly always been used for disc brakes for heavy vehicles in small proportions, in the past asbestos-based pads were used to a greater extent. Asbestos disc brake pads for heavy vehicles are now only used to replace worn asbestos pads in the aftermarket. The switch to semi-metallic pads from asbestos pads is due to the high braking temperatures generated in this application. Semi-metallic pads have superior performance and service life at high temperatures.

Semi-metallic pads for heavy vehicles are made with the same ingredients as those for light/medium vehicles and also may be made with or without an underlayer.

Allied Automotive currently only produces semi-metallic disc brake pads for heavy vehicles. 100 percent of the OEM and most of the aftermarket is held by the semi-metallic pads. The cost of the semi-metallic pad is approximately $12.50 per piece.

Brake blocks are brake linings used on the drum brakes of heavy vehicles -- heavy trucks, buses, and heavy off-road vehicles. Heavy trucks range from moderately heavy, 12,000 -22,000 lbs per axle to very heavy, i.e., tractor trailers and logging and mining trucks. The heavy-vehicle drum brake consists of two curved metal "shoes" to which brake blocks are attached. Each shoe has two blocks, a longer one (the anchor) and a shorter one (the can), resulting in a total of four blocks per wheel. Each block is at least three-quarters of an inch thick and covers 50° to 60° of the arc around the wheel. Each block is riveted to the brake shoe.

Drum brakes for heavy vehicles are either air- or hydraulic-activated, depending on the application. Tractor trailers always use air brakes and medium-sized trucks normally use hydraulic brakes.

Allied Automotive is a relatively small manufacturer of brakes blocks, producing only for the severe braking applications segment of the market (i.e., logging and mining trucks). Allied produces both asbestos and non-asbestos brake blocks in its Cleveland, TN plant.

For the vast majority of applications, i.e. heavy trucks and off-road vehicles, excluding the super-heavy applications (logging and mining trucks), the major group of substitutes are the non-asbestos organics (NAOs). The major substitute for the super-heavy applications, which represent a very small share of the total market, is the full-metallic block.

Allied is in the process of developing a non-asbestos, non-full metallic block. NAO brake blocks have equivalent or superior performance and improved service life relative to asbestos blocks. Allied produces full-metallic brake blocks. These have improved performance over asbestos for extremely high temperature ranges, and they have twice the service life of the asbestos blocks. The price of Allied's full metallic brake block is 83 percent more than the price of its premium asbestos product.

In the event of an asbestos ban, NAO brake blocks will capture the majority of the asbestos-based OEM. The choice of replacement in the aftermarket is more difficult to estimate. Brake systems designed for asbestos brake blocks should continue to use asbestos. Substitute linings which were designed for the OEM, when used to replace worn blocks, do not perform as well as asbestos, and could jeopardize brake safety.

4. Brake Systems (Reference #377, 406, and 435)

Brake Systems Inc., a division of Echlin, purchased Raymark's Stratford, CT drum brake lining plant. Brake Systems also owns Echlin's Dallas, TX plant that was formerly owned by Raymark. The Echlin plant in Dallas, TX is a secondary processor where linings are attached to brake shoes without any additional processing.

Brake Systems also produces NAO drum brake linings.

Brake Systems purchased Raymark's Stratford, CT disc brake pad (LMV) plant. Brake Systems also produces a non-asbestos disc brake pad (LMV) at this plant. Brake Systems produces non-asbestos organic (NAO) pads as substitutes for the asbestos pads but did not indicate it produces them in a sizable quantity.

Brake Systems only manufactures semi-metallic disc brake pads for heavy vehicles at their Stratford, CT plant. This semi-metallic pad contains a very small asbestos underlayer, however Brake Systems does not consider this an asbestos disc brake pad. Brake systems does not manufacture asbestos disc brake pads for heavy vehicles.

5. Wheeling Brake Block (Reference #468)

Wheeling Brake Block in Bridgeport, CT phased out its production of asbestos brake blocks in 1986. The firm currently manufactures non-asbestos brake blocks. These include non-asbestos organics and full-metallic blocks. Wheeling Brake Block only produces their full-metallic blocks in limited quantities and in the past they have generally had poor performance compared to asbestos blocks. However, they have been changing this product recently.

6. Department of Transportation (Reference #659)

This reference was not used in the text and will be deleted from the reference list in the May RIA.

7. Essex Specialty Products (Reference #661)

Essex Specialty Products expects a significant decline in the asbestos extruded sealant tape market over the next several years due to the development of cost effective substitutes, particulary in the area of automotive applications.

Essex produces structural urethane, a major substitute for asbestos sealant tape. It is used to seal automobile windshields and has the a largest share of the market for windshield sealers, 90 percent of the domestic OEM and 60 percent of the aftermarket. Essex expects the market share of the structural urethane to increase and considers structural urethane to be capable of replacing 100 percent of the windshield sealer market. Structural urethane is expected to last 20 years. Its main advantages relative to other sealers are its strength (sheer strength is 700-800 psi) and its lower cost.

8. MB Associates (Reference #666)

Due to the development of cost effective substitutes, there will be a significant decline in the asbestos extruded sealant tape market over the next several years.

9. Parr Incorporated (Reference #667)

Parr Incorporated produces cellulose-fiber tape as a substitute for asbestos sealant tape. Parr's tape is sold primarily for sealing windows on mobile homes and recreational vehicles (RVs). It is less expensive than asbestos tape, however it is not as strong or as heat resistant, and it has a shorter service life. Its service life is fifteen years, and the service life of the asbestos product is 20 years.

TSCA PHONE CALL LOG*

Project: Asbestos

Name of ICF Caller: Rick Hollander

NON-CBI

Organization Contacted: Carlisle, Motion Control Industries Division

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Location:

Name of Person Contacted: Bob Tami

RIA ~~400~~ 378 436 450

62036

R-378

Position of Person Contacted:

Phone Number: 814-773-3185

LOG 2241

Date/Time of Contact: 10/17/86; 1:45 PM

Questions/Responses:

substitute brake blocks are priced 30-50% higher than asbestos blocks.

The majority of the OEM in event of ban (tractor trailers, earth movers, etc.) will be some kind of combination of fibers (NAO):

RIA 378 436 450

75-80% of mkt will be some combination of Kevlar, fiberglass + mineral fibers. Need combine a few to get all of asbestos' characteristics.

steel wool blocks are ~~[illegible]~~ only for very small mkt segment → less than 0.5%.

While the substitute blocks (NAO's) are priced 30-50% higher than asbestos, the initial price increase is overcome because of NAO's longer service life (30% longer life) over asbestos blocks.

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2241

*To be maintained in permanent file.

ICF INCORPORATED

woven vs. molded brake blocks:

woven technology is an older technology. -- more common for clutch facings. Carlisle doesn't make woven brake blocks. These are not very common at all. Molded blocks ~~are~~ riveted onto the the metal brake shoe are the most common type.

disc brake pads HV:

OEM is all semi-metallic. This is a new market. Next 5 years, tractor trailers will be switching over to disc brake pads (similar to what happened in cars).

drum brake linings:

The breakdown of OEM mkt. in event of ban:

#'s are pretty soft

- 40% fiberglass-based (30-50% higher price than asbestos)
- 40% Kevlar-based (30-50% higher price than asbestos)
- 20% chopped steel wool ([illegible] more expensive than Kevlar or fiberglass)

tends to rust + corrode easier

[According to GM, couldn't have fiberglass alone -- more like 1/2 what is semi-met + 1/2 combo's of Kevlar +/or fiberglass +/or other fibers + binder +/or mineral fibers + -(see GM, Jim Main phone log)]

NON CBI

62036

B6-379

RIA 379/409

LOG 2243

Project: Asbestos

BEST COPY AVAILABLE

Name of ICF Caller: Rick Hollander

Organization Contacted: Chrysler

Location: Detroit MI

Name of Person Contacted: Marty Heitkamp

Position of Person Contacted: Engineer, Safety Programs

Phone Number: 313-956-5365

Date/Time of Contact: 11/~~4~~/86, 3:00 PM

Questions/Responses:

For 1986 model year (Sept 1, 1985 - Sep 1, 1986)

RIA 379 409 Chrysler's OEM semi-met disc brake pad consumption had 99.65% with an asbestos underlayer

For 1987 model year, project it to be 91.75% containing asbestos underlayer

Their Suppliers of semi-met disc brake pads that contain asbestos underlayer are:

- Bendix
- Chrysler Chemical Div. (Div of Chrysler)

Suppliers that are 100% asbestos-free are:

- Bendix
- Abex
- Friction Division Products
- VSI - Certified Brakes

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B6 ______ file

2243

*To be maintained in permanent file.

ICF INCORPORATED

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B&380

1758

RIA 380
411
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ASBESTOS SUBSTITUTES IN FRICTION APPLICATIONS

Government restrictions on the use of asbestos having engendered a search for effective, economical alternatives

Steven W Scott, Ph.D., Vice President Research & Development,
Raymark Industrial Division, Trumbull, CT

Ever since huge reserves of asbestos were discovered in Quebec a century ago, American companies have used it in a wide variety of products. Asbestos has been processed into everything from cement pipe to friction products to coatings and compounds.

Friction products, which account for about 14% of the asbestos fiber consumed in the United States, are used primarily in vehicles. Applications include wet and dry brakes and clutches and automatic transmission plates. In addition, industrial components such as oil-well drilling equipment, hoists, cranes, lawn equipment, household appliances, heavy-duty industrial, construction and agricultural machinery, also use friction products.

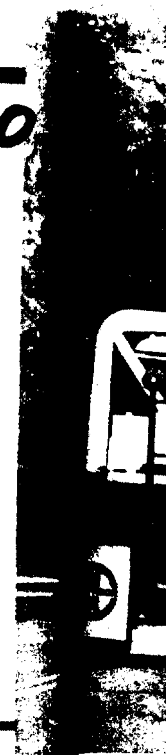
Scanning electron microscope, with X-ray fluorescence capability, is one of many instruments used in product development and analysis.

RIA 549
LoG 1758

A mineral composed of fine, hair-like fibers, asbestos has high tensile strength, flexibility, heat and chemical resistance, and favorable frictional properties, making it adaptable to many applications.

There are several varieties of asbestos. Chrysotile, mined in Canada, is the type most commonly used for molded friction products and longer grade fibers are used in woven goods.

In friction products, asbestos provides structural integrity, strength, temperature and chemical resistance, and good friction properties (i.e., its coefficient of friction does not decrease as temperature increases.) The high strength, aspect ratio, flexibility and large surface area of the fibers, which make intimate contact with the binder system of the products, are what make asbestos so useful.



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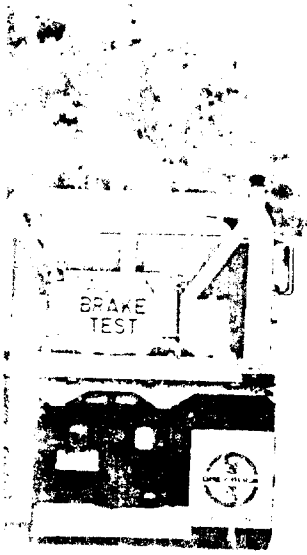
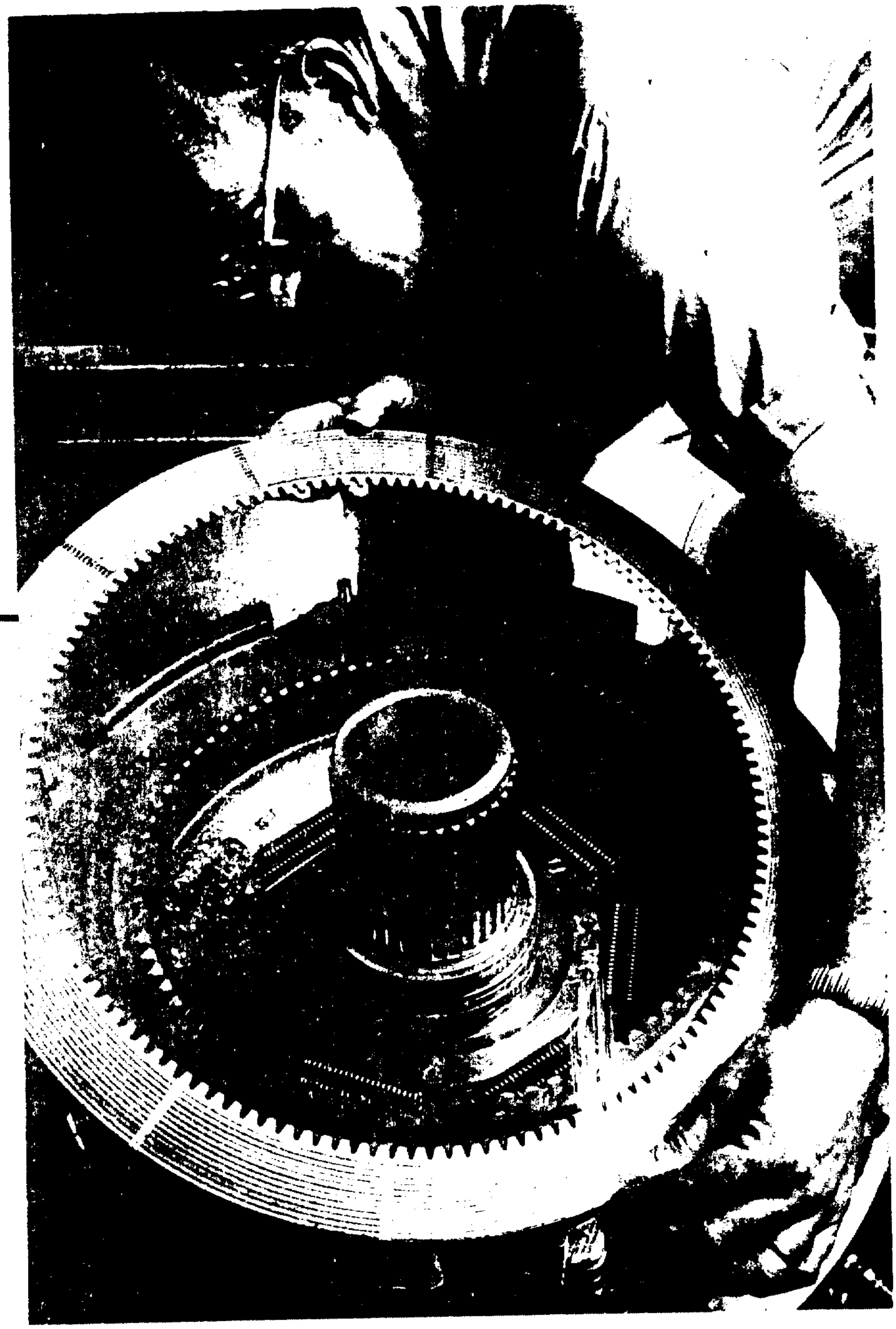


[illegible] ... use in ... to be ... sales ... ing a 75% [illegible]

Although the conversion to non-asbestos materials has proceeded rapidly, it has been far from simple because no one fiber can replace all the different grades. In addition, asbestos' combination of characteristics is so unique there is no one material that can act as a substitute ... in the variety ... to fabricate friction products. Each application requires new materials.

Among the thousands of materials that manufacturers have evaluated for possible use are cotton, glass, carbon fibers, phenolic fibers, aramid fibers, wollastonite, iron (steel wool), ceramic fibers, clay, mica and diatomaceous earth and many other man-made materials. More than 50 materials, with a considerable range in price and availability, are potential replacements for asbestos in friction applications alone.



Friction and reaction plates for power shift transmission undergo performance testing and evaluation in laboratory clutch assembly.

In almost every application, a combination of these materials is needed to replace asbestos. The best combination of fibers must be selected for each product, and new friction material compositions developed around their properties. For example, a brake block composition might contain a low percentage of aramid fibers or graphite fibers for strength and a relatively high level of a mineral fiber to achieve satisfactory cost and processing characteristics. Since each application requires a totally new formulation of substitute materials, the search for substitutes is difficult and costly.

Probably the most challenging aspect of conversion to non-asbestos materials is the question of processing. Asbestos splits into fine fibrils when it is mechanically abraded. While many substitute fibers theoretically lend greater strength to the finished product, they tend to be friable and break up when subjected to conventional asbestos processing methods. Thus, it is often necessary to develop new and better processing techniques in such areas as mixing, drying, and compressing as part of an asbestos elimination program.

Friction products made with asbestos also may contain friction modifiers, organic and inorganic fillers, rubber or elastomers, and resins to bind them into a matrix. Substitute materials may be needed for some or all of these categories when an asbestos substitute is used, compounding the difficulty of developing new products.

The R&D process

Given all the issues involved in finding asbestos substitutes, research and development takes on tremendous importance for the friction products industry. Raymark, whose research efforts have concentrated exclusively on non-asbestos materials since 1975, has invested more than $33 million in the development of asbestos-free products.

In the search for asbestos substitutes, one of the most valuable techniques is the use of computer-aided design (CAD). A new product formulation may have a 30 × 30 matrix of variables. Using the computer to help determine how a change in one variable may affect the finished product, researchers can determine cause-and-effect relationships and explore the extremes of products, materials and processes. CAD helps researchers design experiments and understand their outcome with greater efficiency and effectiveness. As a result, the formulation of non-asbestos friction products has progressed from a hit-or-miss approach to a science.

After a non-asbestos product is developed, it must undergo up to two years of laboratory and field testing before production starts. At its field test facility in Jennerstown, PA, Raymark installs prototype brake block and disk brake products in vehicles to evaluate them on mountain roads.

For original equipment applications, customer testing generally requires another two years. The total period from product development through market introduction takes from four to [illegible] years.

Testing has shown many non-asbestos products to be superior in performance to the asbestos goods they replace. They are more durable and more fade resistant. In some cases, new materials have been used to develop entirely new products that have no asbestos equivalents. These products have opened up new applications in areas requiring very high power absorption, where asbestos could not be used.

While concern that future government restriction could limit the use of asbestos initially fueled the search for replacements, economics and product performance have created a market for them. Non-asbestos products currently being marketed for friction applications generally outperform equivalent asbestos products and are cost-effective.

Passenger cars

The friction market for vehicles is divided into several broad segments, each of which uses a number of products. Passenger cars use disk brake pads, clutch facings, automatic transmission plates and drum brake linings.

An examination of disk brake systems shows how the use of an asbestos substitute affects product performance. The first widespread use of a non-asbestos friction product occurred in front-wheel drive passenger cars. On a rear-wheel drive car, about 70% of the stopping power is on the front brakes. On a front-wheel drive model, 85% of that power is up front, resulting in considerably higher pad temperatures. As the temperature increases, durability and the ability of a brake lining to maintain friction become major considerations. Asbestos-based

Non-asbestos, heat-resistant friction yarns are used to manufacture woven brake linings for industrial applications

ASBESTOS SUBSTITUTES

products can wear rapidly and lose friction at very high temperatures.

Semimetallic disk brake pads, the first major non-asbestos friction product developed in the early 1970's for police cars, ambulances and other difficult applications, are now substituted for asbestos-based disk brake pads. This product exhibits stable friction characteristics with minimal loss of durability as temperature increases. Semimetallics use powdered iron instead of asbestos as well as friction modifiers (usually a combination of materials to give desired frictional conditions) and binders, generally resins.

In normal driving on a front-wheel drive car, semimetallic brake pads have a lifetime of up to 45,000 miles, compared with as little as 10,000 miles for asbestos pads on the same vehicle. Semimetallic disk brake pads are also more energy-absorbent, operating at temperatures as high as 750F without appreciable fade.

Automotive wet friction products are made primarily of paper-type materials, bonded to steel cores, and are used in automatic transmissions. Asbestos-based papers are rapidly being replaced by non-asbestos paper composites, which contain reinforcing materials such as cellulose, cotton and other naturally occurring and man-made fibers.

Non-asbestos substitutes for dry clutch facings in passenger cars and trucks provide the advantages of high energy and lower weight. Lightweight clutches have less inertia, which results in far less abuse and wear of expensive transmission synchronizer gears, and may provide up to 50% wear improvement over asbestos-containing clutches. Burst strength (a clutch creates tremendous centrifugal forces) is also increased as a result of the lower inertia. Smooth clutch engagement, an important concern of all drivers of manually shifted transmissions, is an added advantage of non-asbestos clutch facings.

Medium- and heavy-duty trucks

Heavy-duty trucking equipment uses a variety of friction materials. Asbestos-based brake blocks are being replaced by products combining high-temperature resins, friction modifiers, and natural and man-made fibers. These new asbestos-free blocks have the highest durability of any brake block on the market, as much as twice that of current asbestos products.

Disk brakes are beginning to replace brake blocks in heavy-duty trucks, and may eventually revolutionize the trucking industry. During the next 10 years, the switch from brake blocks to disk brakes is predicted to be dramatic. Semimetallic disk brake pads allow safer stops with greater axle loads. Consequently, trucks may be designed that can carry larger axle loads, or that may need less friction material to brake.

Originally, asbestos-based clutch facings were used in heavy-duty truck applications. About half of the market converted to sintered bronze buttons because of their greater durability and ability to withstand higher temperatures. Unfortunately, sintered buttons do not engage smoothly.

The market is now reexamining the same type of non-asbestos clutch facings as are used in the passenger car and light truck markets. These are almost as durable as sintered buttons but have vastly improved engagement ability. The clutch facing material incorporates fiberglass and other temperature-resistant, man-made fibers in a proprietary blend, and includes friction modifiers, high-temperature resins, and elastomers. Because of its lower weight and improved durability and burst strength, this material

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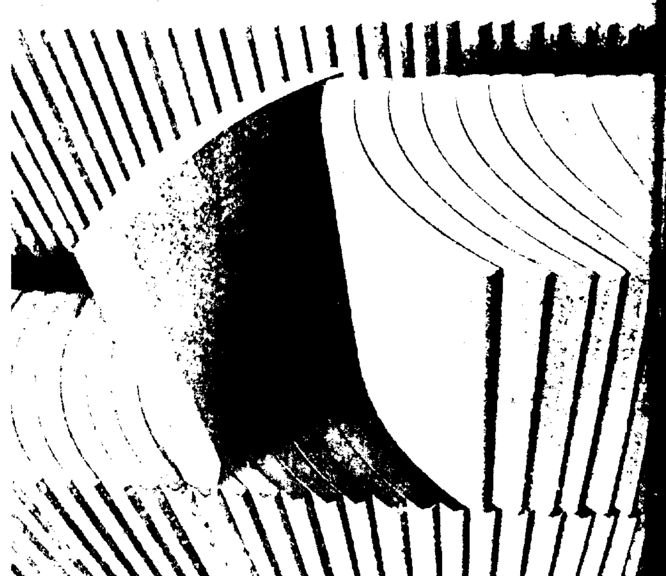
Raymark's heavy-duty, non-asbestos, semimetallic air disk brake is used by major brake system manufacturers. Product is less expensive and performs better than asbestos counterparts.



After six years of development and 17,500 hours of brake dynamometer testing, Raymark introduced new, non-asbestos brake block in 1982, which extends brake lining life by at least 35%.

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ASBESTOS SUBSTITUTES

also provides the advantages of greater design flexibility, higher horsepower loading and weight savings.

Off-road vehicles

Off-road vehicles include heavy-duty construction, mining and agricultural equipment. This portion of the friction market uses oil-cooled clutches and brakes, sometimes referred to as wet friction products, because of severe operating conditions and design considerations. Fluids facilitate the transfer of heat away from the working surface of the friction material providing superior durability and resulting in longer life between major overhauls and replacement. Applications include powershift transmissions, oil-cooled wheel brakes, power take-off clutches, steering clutches and brakes.

The friction material elements vary according to the application, the operating conditions, and the design concepts employed by many different manufacturers.

Sintered bronze friction plates were primarily used during the 1950s and 1960s. Since then the trend has been toward paper-type, graphitic and elastomeric products because of their performance, versatility and cost effectiveness. They are composed of advanced fibers, fillers, resins and elastomers.

Non-asbestos products should account for most of this market in the next few years.

Industrial products

Many other industrial, non-vehicular friction applications also use asbestos substitutes. This is a complex area with a wide range of materials and applications, most of which require very specialized evaluation procedures. Nevertheless, a broad range of products is now available, including woven and molded linings, molded rings, industrial brake segments and special molded parts for both wet and dry friction applications.

Work on asbestos substitutes has been particularly strong in products for the oil well drilling and construction industries. The oil well industry uses woven friction band materials for maximum efficiency and smooth control. A specific type of glass was found that can be processed economically and woven into the required large sizes. A special, compatible saturant system also had to be developed. A slightly modified version of the basic glass-brass woven tape is used in light-duty general-purpose band brake applications.

A flexible, non-woven, non-asbestos material has also been developed for many small band brake applications. The major hurdle here was to develop a binder system that would provide the desired physical strength and friction and wear properties. In addition, the positive aspects of asbestos, such as heat resistance, fiber length and aspect ratio, and superior reinforcing value, had to be matched by materials whose inherent properties were significantly different than asbestos.

Glass fibers, minerals and resins are used to make gear-tooth clutch facings for heavy-duty equipment such as pavement rollers and industrial machinery. Special non-asbestos friction products have been developed for equipment such as lawn mowers, washing machines and machine tools. Some chain saws are now equipped with non-asbestos dry clutch linings.

Future of friction materials

Many asbestos-free friction products for vehicles are now available. The friction materials market is on the verge of an explosion of non-asbestos products. By 1985, approximately 50% of all original equipment vehicular friction material products will be asbestos free. Many of the technical breakthroughs have been achieved and they are now beginning to reach the marketplace. As the non-asbestos products start to be used, they will have an impact on vehicle design, making new capabilities possible. ☐

FORD MOTOR CO.
OPTS Docket #62036 Asbestos Ban File
MC/E ____________
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V. H. Sussman, Director
Stationary Source Environmental Control
Environmental and Safety Engineering

Ford Motor Company
Suite 608
15201 Century Drive
Dearborn, Michigan 48120

June 26, 1986

Document Control Officer (TS-790)
Office of Toxic Substances
Environmental Protection Agency
Room E-201
401 M Street S.W.
Washington, D.C. 20460

Attention: Docket Control No. OPTS-62036A

Subject: Proposal to Amend 40 CFR 763 -- Asbestos; Proposed Mining and Import Restrictions and Proposed Manufacturing, Importation and Processing Prohibitions 51 Fed. Reg. 3738 (1986), as corrected at 51 Fed. Reg. 6571 (1986)

Ford Motor Company ("Ford") hereby responds to the Agency's request for comments on the above-referenced proposed rule. Ford adopts the comments submitted in this docket by the Motor Vehicle Manufacturers Association of the United States, Inc. ("MVMA") to the extent that MVMA's comments are consistent with the following.

Ford opposes the proposed permit system for allocation of asbestos during a phasedown of asbestos mining and importation. The proposed permit system would impose significant costs on the regulated community for administration, permit acquisition, tracking asbestos content of imported products, reporting and recordkeeping; these costs are understated in the Regulatory Impact Assessment.

The permit system would discriminate against importers of motor vehicles and vehicle components. The baseline years for initial allocation of permits are years in which the automobile industry and the economy were in a downturn. Additionally, the amounts of asbestos imported in automotive products during the baseline years do not reflect the change in such amounts occasioned by the more recent shift toward multinational manufacture and sale of vehicles and components. Ford, for example, imported far fewer asbestos-containing vehicles in those base years than it has imported more recently. To now allocate permits on the basis of amounts imported during those unrepresentative base years would unduly penalize Ford (and presumably other vehicle importers).

The permit system also ignores the practice in the automobile industry of introducing changes during model redesign. These changes such as substitution of non-asbestos materials are not the uniformly stepped incremental changes envisioned by the proposed 3% per year reduction, but are major steps which might affect 30% of production in a single year. Each of these major changes involves substantial engineering/design/testing time and expense, tooling design/manufacture time and expense, facilities design/construction time and expense, and, with the permitting system, additional administration/overhead time and expense, all of which will be reflected in consumer cost and which, when uncoordinated with model changes, will be significantly greater than forecast by the RIA.

Ford supports a reasonable fixed timetable for removal of asbestos products, coupled with a procedure for exempting those essential asbestos products for which no reasonable alternatives exist. In this regard Ford's suppliers of asbestos products inform us that they do not yet have practicable asbestos-free substitutes for certain asbestos-containing components such as heavy truck brake blocks and disc pads, and some duo-servo car and light truck drum brake linings, engine manifold gaskets, and exhaust system gaskets and heat shields.

Motor vehicle safety must not be compromised. Even a slight increase in traffic fatalities would eliminate any benefits from the reduction in cancer cases projected by the Agency.

The Agency has requested comments on whether asbestos brakes now in use may be safely replaced by asbestos-free brakes when they wear out. Ford has already touched on this question in its response of March 15, 1985 (Document Control No. OPTS-211015). A simple assumption that a brake shoe made of one material can be substituted for a shoe made of another material without extensive engineering evaluation is not correct. Many different performance, noise, durability, and other problems can occur when a friction material is introduced into a system without careful evaluation. Many complex issues must be researched including, but not limited to, thermomechanical stability ("hot spotting" and "banding"), brake fluid displacement, fluid boil (semimetallic and metallic linings), morning sickness (effects due to moisture), and different friction levels. For example, Ford Heavy Truck Engineering recently found that in some vehicles, substituting non-asbestos brake shoes for those containing asbestos necessitated major changes in the air brake actuation systems including larger reservoir and brake chambers and increased compressor capacity. The extension of this experience to the 192 different brake systems and 51,000 parts currently in inventory at the Ford Parts and Service division which contained asbestos is simply enormous. This large inventory of parts is held as parts replacement for vehicles designed over the past 29 years. Thus, Ford strongly recommends that EPA exempt the manufacture and sale of asbestos-containing service components for vehicles which were originally designed and equipped with systems that consist of asbestos-containing brake shoes and pads.

The Agency also has requested comments on labeling of asbestos-containing parts subject to regulation 5 or 10 years from now. Ford currently labels the package of its asbestos-containing brake shoes, brake pads, and clutch plates with a warning that the parts contain asbestos fibers and that breathing asbestos dust may cause serious bodily harm. The label also specifies precautions which should be taken during service. Sample labels for the packages for both brakes and clutches are attached. Ford sets forth more detailed instructions for safe servicing of these friction products in its shop manuals.

These types of warnings directed to those about to install asbestos-containing friction components most effectively protect those most likely to come into contact with the dust residues of braking and clutching. A simple content warning provides little useful information to the consumer because it gives no information about a specific potential hazard and no information about how to avoid that hazard. Labeling of asbestos components as installed in vehicles is impracticable. Many parts are too small to be labeled and the environment of some parts, e.g., the high-temperature environments of brakes and clutches, would destroy labels. The point at which the warning, when necessary, should be delivered is at the replacement part/service operation.

Very truly yours,

Victor H. Sussman

Attachment
jlt3/L

TSCA PHONE CALL LOG*

NON-CBI ?
MG.

RIA 384
416

LOG 2242

Project: Asb. Use and Substitutes Analysis

Name of ICF Caller: Rick Hollander

Organization Contacted: GM, Delco Moraine Div.

Location: Dayton (? or Warren, MI)

Name of Person Contacted: Frank Brookes

Position of Person Contacted: Engineer

Phone Number: 513-455-6574

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B6-384

Date/Time of Contact: 11/19/86 4:30pm

Questions/Responses:

Types of parking brakes

① Disk } use existing service brakes in the rear
② Drum }

③ Front Parking brake - disc
④ Seperate parking brake as Drum Brake
- internal in the rear and separate from the rear drum brake

RIA 384
416

GM's four disc-brake cars (front + rear)

Cadillac Seville, El Dorado, High Performance Camaros + firebirds, Pontiac STE, Pontiac Fiero

Camaro + Firebird have asbestos rear discs and semi-metallic front disc brakes. There is no particular reason for this - they just started out doing it this way and alot of work is required to switch over. Engineering and to revalidate (validate refers to passing GM performance standards)

2242

Imports w/ 4 ~~disk~~ disc brakes (front + rear)

Superwy imports e.g. Mercedes, BMW

*To be maintained in permanent file.

ICF INCORPORATED

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- Disc brakes have longer life than drum brakes. Disc generally are better at removing heat quickly which is important for cars stopping alot at lights + stops at higher speeds

- Most cars, especially front wheel drive, rear brake doesn't do much work, so it doesn't need too much breaking performance because less brake load. Brake force is mostly in front. For rear drive cars there is still even less brake force in the rear than in the front.

- Drum Brake

  - Never will get rid of drum brakes if asbestos banned (we won't switch to four disc brake vehicles) because drumbrakes are so economical.

  - Adv. and disadvantages

    - parking brakes work better if drum brake
    - more economical than disc -- since drums are just for the rear where there isn't as much brake load, they have the same service life as disc brakes in rear
    -
    - Drum brakes cost much less to produce than disc brakes

- Non-semi-metallic, non-asbestos disc brakes for LMV (These are most likely NAOs) in OEM are a very small %. Almost all disc brakes in OEM are semi-metallic

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- Wagner – involved in aftermarket, possibly in OEM in trucks

- Only ~5% of domestic OEM cars have four disc brake systems. Luxury, high end of market. Light trucks don't use ~~4~~ disc brake systems

- Nearly 100% of all LMV's, whether front or rear-wheel drive use front disc brakes and rear drum brakes.

- 2 disc brake pads per wheel
- 2 drum brake linings per wheel or per drum

For 95% of OEM LMV's there is a 1:1 ratio for disc + drum brakes (2 disc + 2 drum brakes)

~~100~~ 5% of OEM LMV ~~LMV's or~~ cars have 4 disc brakes

No OEM LMV trucks have 4 disc brakes.

GENERAL MOTORS

OPTS Docket # 62036 Asbestos Ban
Request to Extend M/C E 50 File

Environmental Activities Staff
General Motors Corporation
General Motors Technical Center
30400 Mound Road
Warren, Michigan 48090-9015

GM

'86 MAR 20 PM 3:49

62036
E 50a

March 14, 1986

Document Control Officer (TS-793)
Office of Toxic Substances
Environmental Protection Agency
Room E-209
401 M Street SW
Washington, D.C. 20460

Gentlemen:

General Motors Corporation (GM) hereby requests a 60-day extension of the comment period for the proposed amendments to 40 CFR Part 763 (Docket Control Number OPTS-62036). These proposed regulations are concerned with the restrictions on the mining and importation of asbestos and the prohibition of the manufacturing and processing of certain asbestos-containing products.

GM is primarily concerned with the potentially far reaching ramifications of the proposed regulations dealing with asbestos-containing friction products. EPA has also asked for comments on a number of specific questions relating to this concern. For GM to provide meaningful comments on these questions (including exemptions for aftermarket asbestos brakes, and labeling of asbestos-containing friction products) as well as to answer EPA's question on whether the proposed regulations, or one of the alternatives, or a combination of the alternatives would be in the best interest of public safety requires analysis of a broad matrix of possible ramifications.

GM appreciates EPA's receptiveness towards comments and suggestions on these proposed rules but believes that an extended comment period is necessary for a meaningful response. Accordingly, GM requests that the comment period be extended, past the public hearing period, to June 29, 1986.

Sincerely,

Joseph P. Chu

Joseph P. Chu
Assistant Director
Plant Environment

USEPA, TO ~~GM~~ GM Corp
OPTS Docket # 62036 Asbestos Ban
M/C E 506 File

Rigby

62036
E 506

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

APR 11 PM 12 58

OFFICE OF
PESTICIDES AND TOXIC SUBSTANCES

Mr. Joseph P. Chu
Environmental Activities Staff
General Motors Corporation
30400 Mound Road
Warren, Michigan 48090

APR 11 1986

Dear Mr. Chu:

Thank you for your letter of March 14, 1986 to the Document Control Officer requesting a 60-day extension of the comment period for the proposed rule to ban certain asbestos products and phase out other such products. Because of the complexity of this rulemaking, we will extend the comment period as requested.

I look forward to your participation in the rulemaking.

Sincerely,

David Dull, Acting Director
Chemical Control Division

General Motors
OPTS Docket # 62036 Asbestos Ban
M/C E 50 C File

270

GM

62036
E50c

86 JUL -1

Environmental Activities Staff
General Motors Corporation
General Motors Technical Center
30400 Mound Road
Warren, Michigan 48090-9015

1986 JUN 30 PM 3:52

June 29, 1986

Document Control Officer (TS-790)
Office of Toxic Substances
Environmental Protection Agency
Room E-201
401 M Street SW.
Washington, D.C. 20460

RE: DOCKET CONTROL NUMBER OPTS-62036A; FRL 2999-2

Gentlemen:

Attached is the General Motors Corporation's statement on the proposed amendments to 40 CFR Part 763 (Federal Register, Vol. 51, No. 19, January 29, 1986, pages 3738-3759). These proposed regulations would restrict the mining and importation of asbestos and prohibit the manufacturing and processing of asbestos-containing products.

General Motors has carefully evaluated the proposed regulation's effect on the automotive industry's current uses of asbestos and the EPA's analysis of the health effects of those uses of asbestos. Many motor vehicle brake systems rely on asbestos-containing friction materials to meet performance requirements of the National Highway Traffic Safety Administration [NHTSA] and customer expectations. The task of engineering systems that use non-asbestos friction materials is enormous. No effective substitute has yet been found for a sizable number of these systems.

General Motors believes that flaws in the health risk estimates have led to an overestimation of risk attributed to the use of asbestos friction materials. Consideration should also be given to the safety risks which would be created by the premature elimination of all asbestos friction materials from motor vehicles.

While General Motors continues to question the need for the EPA proposed phase-down of asbestos, GM believes that the selective ban of asbestos friction products after a period of 10 years is more practicable than any of the EPA proposals.

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General Motors strongly urges the EPA to confer with the NHTSA to assure that changes in performance which may result from the forced use of non-asbestos materials are acceptable from a motor vehicle safety perspective. Failure to reconcile the potentially conflicting requirements of the two agencies would place vehicle manufacturers in an impossible position because they would be caught between different requirements of environmental and safety regulations.

General Motors also urges the EPA to reexamine the neccessity of these proposed regulations in light of the newly amended regulations concerning occupational exposure to asbestos promulgated by the Occupational Safety and Health Administration. OSHA has determined that its new exposure standard will significantly reduce lifetime health risk from occupational exposure.

Thank you for the opportunity to comment on this issue. If you have further questions or wish to pursue any of the points in more detail, please contact me at (313) 575-8602.

Sincerely,

Joseph P. Chu

Joseph P. Chu
Assistant Director
Plant Environment

Att.

cc: Ms. Diane Steed, Administrator, NHTSA
Mr. Barry Felrice, Associate Administrator, NHTSA
Ms. Erika Jones, Chief Counsel, NHTSA
NHTSA, Docket 85-06

E-050c(001)

GENERAL MOTORS CORPORATION
STATEMENT ON
ASBESTOS; PROPOSED MINING AND IMPORT RESTRICTIONS AND PROPOSED MANUFACTURING, IMPORTATION AND PROCESSING PROHIBITIONS
(Docket OPTS-62036A, FRL2999-2)

June 29, 1986

INTRODUCTION

The EPA's proposed regulations would restrict the mining and importation of asbestos and prohibit the manufacturing and processing of asbestos-containing products. The EPA's proposal is to ban the use of asbestos in certain construction products and clothing immediately and to "phase-down" the use of asbestos in all other products. The phase-down involves a permit system in which persons who have mined or imported asbestos or asbestos-containing products in 1981-1983 will be granted permits to mine or import only 30% of the average amount of asbestos they mined or imported during 1981-1983 when this proposed rule becomes effective. The percentage will then be reduced by 3% per year.

General Motors [GM] is a manufacturer and user of asbestos friction materials and a user of other asbestos products. A careful evaluation of GM's current asbestos usages and particularly the usage in automotive brake systems, indicates that neither the EPA's proposed phase-down schedule nor any of the three EPA suggested alternative schedules are reasonable or practicable.

The EPA's basis for proposing such stringent regulations is questionable. GM believes that: 1)the EPA has not satisfactorily demonstrated, at least in automotive friction product applications, that the current patterns of asbestos usage present an unreasonable risk to human health; 2)the EPA has not adequately considered the availability of non-asbestos substitutes and the possible health risks associated with these substitutes; and 3) the EPA (even if it can establish a reasonable health risk basis for proposing regulations on asbestos phase-down) has not proposed a viable regulatory proposal.

The EPA is urged to confer with the National Highway Traffic Safety Administration [NHTSA] on this rulemaking to assure that changes in performance which might occur as a result of the forced use of non-asbestos friction materials is acceptable from a motor vehicle safety perspective. Failure to reconcile the potentially conflicting requirements of the two agencies would place vehicle manufacturers in an impossible position because they would be caught between different requirements of environmental and safety regulations.

The EPA should also reexamine the necessity of such stringent regulations in light of the new permissible exposure level [PEL] for asbestos that has been set by the Occupational Safety and Health Administration [OSHA] in Federal Register Vol. 51, No. 119, June 20, 1986. The new PEL, at 0.2 f/cc (fibers per cubic centimeters), is 10 times lower than the previous standard and OSHA believes that this new PEL will significantly reduce occupational risk.

Finally, General Motors has participated in the development of the comments which have been filed by the Motor Vehicle Manufacturers Association [MVMA]. Where consistent with this response, GM concurs with the MVMA comments and incorporates them herein by reference.

RISK TO HUMAN HEALTH

EPA's Finding of Unreasonable Risk

The EPA's finding of unreasonable risk is based on its estimates of the number of cancer cases that are identified as avoidable if the proposed rule is implemented. These estimates are the result of EPA's dose-response modeling of lung cancer and mesothelioma. GM believes that the EPA's model overestimates the risks and that a sufficient basis for banning all uses of asbestos, therefore, has not been established.

It should be recognized that the modeling of dose-response relationships between asbestos exposure and asbestos-related diseases is limited by the inherent deficiencies of epidemiological and animal studies. Dose-response data from epidemiological studies are often lacking, as in Selikoff's study (Selikoff et al., 1979) of insulation workers, because of a lack of asbestos air monitoring data.

Even if accurate dose-response data were available, the range of past exposures to asbestos as well as other hazardous substances experienced by study populations is typically much higher than current levels of exposure. Models that are developed on the basis of such data are potentially unreliable tools for estimating the effects of current exposure and must not be used until they are validated.

The dose-response model for lung cancer and mesothelioma chosen by the EPA is based on epidemiological studies on worker populations that have experienced exposures that are orders of magnitude higher than current levels. Although others have used models of similar structure, the validity of the models' assumptions is by no means noncontroversial. For example, it has not been clearly established that the dose-response relationship for lung cancer is linear and has no threshold concentration. The validity of the method by which the values of the model's parameters (dose-response constants) were chosen is also questionable.

In the Appendix to Chapter 7 of the Report of The Royal Commission on Matters of Health and Safety Arising from the Use of Asbestos in Ontario (1984) [Ontario Report], Ronald J. Daniels and Robin S. Roberts noted that Selikoff's study does not contain any measurements of past exposure, and further commented that "the lack of accurate exposure data greatly detracts from the value of the study in providing proportionality constants for dose-response modelling."

In part of the same Appendix ("Predicting Workplace Health Risks"), Daniels and Roberts analyzed seven major epidemiological studies of asbestos workers (McDonald, 1971 & 1980; Enterline et al., 1973; Peto, 1977 & 1980; Dement et al., 1982; Berry and Newhouse, 1983; Finkelstein, 1983; Selikoff et al., 1979). They attempted to predict excess lung cancer risk from each study using a model that is structurally similar to the one chosen by the EPA (i.e. linear dose-response with no threshold.) The resulting predictions from these particular exposures to asbestos fibers differed by more than a factor of 100.

It appears that the EPA has not recognized that the predicted excess cancer risk for any given level of fiber exposure (e.g. 2 f/cc or 0.2 f/cc) is highly sensitive to the data from which a model is developed. It is interesting to note that in Daniels and Roberts' analysis of the excess cancer risk predicted from Selikoff et al.'s (1979) study of insulation workers was nearly 17 times greater than that predicted from Berry and Newhouse's (1983) study of factory workers producing friction products.

It is not suggested here that the EPA should combine risk estimates that are generated from the various studies to obtain an average value of excess cancer risk. Rather, it is suggested that the EPA recognize that the wide range of risks may be the result of measuring different risks. The Ontario Report as well as others have concluded that different risks are associated with different asbestos fiber types.

It has been recognized that prior exposures to chrysotile (the type of asbestos used in friction products) resulted in lower rates of asbestos-related diseases than exposures to crocidolite or amosite. This difference is generally believed to be attributable to differences between the fiber morphology and crystal structure among these three types of asbestos. Long, thin fibers are thought to pose the highest risk. Crocidolite and amosite are more biologically active than chrysotile. The Selikoff et al. (1979) study involved workers that were exposed to both chrysotile and amosite. The EPA's use of these data for estimating future cancer risks that will almost exclusively be associated with low levels of exposure to chrysotile is inappropriate.

Since health hazard is strongly associated with the dimensions and airborne concentrations of fibers, it is also recognized that for a given type of asbestos fiber, the health risk is associated with the manner by which the fiber is released into the environment. It can therefore be inferred that the spraying of asbestos insulation is far more hazardous than the manufacturing of brake linings. This indeed has been shown to be the case. As noted above, Daniels and Roberts (1984) estimated that the excess cancer risk for insulation workers is nearly 17 times greater than that for factory workers making friction products. This raises serious doubt about the appropriateness of the EPA's use of data from a particular epidemiological study where exposure to mixed asbestos types occurred to predict cancer risks arising from all current and future manners of exposure, levels of exposure, and asbestos types.

The EPA's use of the data from Selikoff et al. (1979) for the development of their dose-response model for mesothelioma also appears to be inappropriate when, in fact, mesothelioma is more strongly associated with exposure to crocidolite and amosite rather than exposure to chrysotile. The EPA also claims that it has underestimated mortality because mortality from asbestosis and cancers other than lung cancer was not quantified. GM believes that this claim is unjustified. Clinical asbestosis among the general public has never been documented and the Ontario Report concluded that "asbestosis [among asbestos workers] can be deemed a disease of past high exposure levels and will not occur in workers exposed to the regulated levels of occupational exposure now in force in Ontario." Although it has been suggested that the inhalation of asbestos may cause gastrointestinal cancer and cancer of the larynx, an association between asbestos exposure and these diseases has not been firmly and consistently established in the literature.

GM believes that the EPA has overestimated the amount of asbestos exposure arising from brake maintenance and repair. The amount of chrysotile asbestos in brake dust samples have been measured to be less than 1% by weight (Williams and Muhlbaier, 1982). Potential exposure to asbestos during the servicing of automobiles has been regulated under OSHA 29 CFR 1910.1001 and will be even more closely regulated under the amended version. In addition, Appendix F of the new OSHA standard 29 CFR 1910.1001 suggests work practices which OSHA believes will prevent exposure levels from exceeding 0.1 f/cc.

The EPA has overestimated the risk arising from the use of asbestos friction products. As a result, the urgency of a total and expedited phase-down of asbestos in these uses is not warranted.

Potential Health Risks of Nonasbestos Substitutes

While the EPA notes the apparent lower carcinogenicity of current non-asbestos substitutes, it seems to overlook the risk that may be present and the paucity of studies of some of the substitutes. This is a concern because of the apparent association of biological effects with certain physical characteristics of fibers such as morphology and durability. There is the potential that the use of substitute fibers, especially without controls, may cause exposures to fibers similar to those asbestos fibers which pose health risks. Total risk may be minimized only by regulations which reduce the amount of exposure to fibers of critical size, whether asbestos or other fibers. The EPA also should recognize that virtually all substitute materials require considerably more study to determine their health hazard potential.

GM, in its efforts to find suitable substitutes, has not overlooked its responsibility to determine the potential environmental and health impact of the use of such materials. Along with the development of its semi-metallic brake friction material as a replacement for asbestos friction material, GM has also conducted research to study potential adverse health effects. The results of our work indicate that the debris generated by the use of semi-metallic materials as brake linings constitutes no unusual health hazards beyond that of a nuisance dust.

As GM continues its efforts to find other suitable materials, parallel efforts are underway to assess potential risks. Among the new materials being tested are aramid fibers. Although there are currently no reports that there is a relationship between exposure to aramid fibers and adverse health effects in humans, inhalation toxicology data of Lee et al. (1983) and E.I. DuPont De Nemours & Co. (April 4, 1985 letter from Dr. Charles Reinhardt to Document Control Officer (WH-557), U.S. EPA) have indicated that the possibility of lung tumors from chronic, high level exposures in animals does exist. GM is continuing its evaluation of aramid fibers.

Because of the current lack of information on human health impacts of new substitute materials and the uncertainties with the extrapolation of available data to human exposure at lower fiber concentrations for longer periods of time, it is inappropriate to mandate a transition to such materials.

The concern that has been expressed here is really only one facet of a more generalized concern, the concern that risk not merely be transfered from one environment to another and that the net risk to public health and safety not be increased by the proposed regulations. While the intent of the EPA's proposal, undoubtedly, is to reduce net human health risks, it is not clear that the EPA has given adequate consideration to the possibility that their proposal to reduce risks from asbestos may in fact have the unintended effect of substituting the risk of untested non-asbestos substitutes and lower motor vehicle safety for the asbestos risk.

The mere transference of risks at great expense and hardship is an unacceptable, though possible, consequence of the proposed regulations. More unacceptable, though equally possible, is that the net risk will be increased. Substitute materials and motor vehicle safety are only two of several possible areas to which the risks associated with the use of asbestos in vehicle applications may be transfered. To avoid such possibilities, GM urges the EPA to consider the benefits of the proposed regulations from a net risk perspective.

REGULATORY ACTION

If the EPA is insistent on a regulatory phase-down of asbestos under Section 6 of TSCA despite the questionable basis for such an action, then GM believes that the EPA must propose regulations that can be implemented in an orderly manner without unnecessary burden on the regulated community and affected public.

Cost-Effectiveness

Section 6 of TSCA requires that the regulations necessary for adequate protection against an unreasonable risk be the least burdensome. GM believes that the proposed Subpart H (Sections 763.140-763.159) as well as the EPA's proposed alternatives do not meet this requirement. The EPA's own Regulatory Impact Analysis of Controls on Asbestos and Asbestos Products (January 1986) [RIA] presented a more cost-effective alternative.

Six alternative regulatory strategies are analyzed in the RIA. The summary of the costs-benefits analysis for each alternative and the sensitivity of the analysis to the OSHA PEL for asbestos are presented in Table 8 and Table 13 of the RIA.

Alternative C of the six alternatives in the RIA would ban the use of asbestos only in the construction products category and in clothing. By eliminating a major portion of the asbestos market through this ban, the extent of asbestos mining, importation, and usage in other products will then be automatically curtailed by market forces.

According to the RIA, Alternative C, which was not presented in this notice of rulemaking, is the most cost-effective regardless of the OSHA PEL for asbestos. From the cost-benefit ratios in

Tables 8 and 13 of the RIA, Alternative C is three to five times more cost-effective, depending on the discount rate, than the EPA proposal (Alternative B) or any of EPA's three suggested alternatives (Alternatives D, E, and F).

The significance of differences in benefits achieved by Alternative C and the EPA proposal must be considered in light of the predictive accuracy of the EPA's model. These difference may not be real. Given the uncertainties in the data from which the model was derived and the assumptions in the selection of the model parameters, the variance of the model estimates, in all likelihood, overshadows differences of this magnitude. GM, therefore, believes that the EPA should find that Alternative C is the most cost-effective and will achieve the same level of benefits as its own proposal.

In addition to being the most cost-effective alternative, Alternative C would also avoid the administrative burdens associated with the proposed permit system. The establishment of an exemption system for applications in which non-asbestos substitutes cannot be found in time to meet the phase-down schedule would also be likely to be unnecessary.

Elimination of Asbestos from Friction Products

GM believes that the proposed ban of asbestos-containing friction products is unneccessary and that the phase-down schedules in the EPA's proposal and suggested alternatives are inappropriate. If banning of asbestos friction products is to be required, GM believes that a more practicable approach is for the EPA to pursue a program which would begin to ban the use of asbestos friction products in original equipment passenger cars and truck applications up to 23,000 pounds Gross Axle Weight Ratings (GAWR) after a 10 year period. In addition, there must not be any restrictions on the supply of asbestos (i.e. no permit system).

Even the EPA's own RIA showed that there is essentially no additional benefit to be gained from the phase-down of asbestos containing friction products or any other asbestos containing products beyond the construction products category and clothing category. If the EPA is insistent on banning of asbestos containing friction products despite the lack of a basis for such a ban, then the phase-down should at least follow a schedule which allows for the orderly discovery and validation of alternative materials.

Although GM has been active for many years in seeking substitutes for friction products, difficulties have been encountered which have prevented widespread substitution of asbestos. Factors that must be considered in selecting suitable substitutes have been detailed in GM's April 17, 1985 response to Docket OPTS-211015. The process of developing and approving substitute materials includes assessing the ability of the material to meet durability, consumer acceptability, and federally mandated safety requirements. This process requires extensive research and testing programs.

The EPA has stated that effective substitutes are not available for many brake applications. GM agrees. GM further states that there is currently no known substitute material that can deliver the same brake system performance as asbestos for all applications even with modification to other components of the brake system.

The predominant non-asbestos brake friction material substitute being used by GM is of semi-metallic composition. These materials are now successfully used in nearly all disc brake applications on GM passenger cars and light duty trucks. It should be noted that the transition to semi-metallic linings was primarily motivated by the need to meet the stringent requirements of the Federal Motor Vehicle Safety Standard 105 [FMVSS 105], particularly the fade and recovery provisions for small, fuel efficient vehicles.

Some disc brake systems, however, still contain an asbestos underlayer that is used as a thermal barrier as well as an aid to attaching the lining to the metal backing plate. Development efforts are already underway to find a suitable non-asbestos underlayer material.

GM uses asbestos drum brake linings on nearly all of its vehicles. Designing systems to use non-asbestos drum brake linings is more difficult, as described in our April 17, 1985 comments. GM has used non-asbestos drum brake linings on two models and is developing them for additional applications. The NHTSA, however, has initiated an engineering analysis in one case and a defect investigation in the other. Action by the NHTSA may further complicate the search for non-asbestos linings.

Currently, in order to remove trade barriers, an effort is underway to harmonize the two existing dominant passenger car brake standards, the U.S. FMVSS 105 and the European ECE 13, into a single harmonized standard. As part of this effort, NHTSA has initiated rulemaking, and proposed a new FMVSS 135 as a U.S. proposal for the harmonized standard. The NHTSA proposal is more stringent than the two existing standards. More importantly, if enacted as a final rule, the proposed standard would have the effect of establishing more stringent constraints on the selection of brake lining materials. It would make the task of eliminating asbestos from brake systems more difficult, if not impossible, with currently available substitutes. To aid the EPA in understanding the complexities of brake system design and the contribution of lining materials to the performance of brake systems, General Motors comments to the proposed FMVSS 135 are included here as an attachment. General Motors believes that a full consideration of this information by the EPA is of fundamental importance to this asbestos rulemaking.

Another obstacle to more rapid and widespread substitution for asbestos in brake linings is the enormous scope of the program that is necessary to address the large number of brake systems that are used in current vehicle applications. Each application (combination of vehicle type, weight, brake design, etc.) requires a different combination of material and physical components.

Over the next several years GM will be utilizing about 75 new passenger car and light duty truck brake systems. Approximately 15 systems will be used for medium and heavy (less than 23,000 lb. GAWR) trucks. For most drum brake systems, suitable non-asbestos compounds have not been identified. Once a suitable material is identified, another 18 to 36 months are used to validate (field test) the brake system to ensure that all performance requirements are met (e.g. FMVSS 105 or 121, durability, customer satisfaction, etc.). The total development cycle for any single brake system, including the identification of a suitable compound could require five years or more, depending upon the difficulties which are encountered. For these reasons, GM believes that a period of 10 years is a more practicable schedule for the selective elimination of asbestos friction products from most new vehicle applications.

For certain heavy truck applications (i.e. applications involving GAWR in excess of 23,000 lb. single/46,000 lb. tandem), there is currently no known substitute material that will meet performance requirements. Although GM does not manufacture brake linings for these applications, we have been working with our suppliers in developing the necessary technology, but progress has been very limited. Because of the difficulties to date and the need for "inventions" of a new material to meet these special, low volume applications, GM is unable to predict when asbestos can be eliminated. Disc brake systems have not been developed to replace existing drum systems for trucks in these heavy weight classifications.

Aftermarket Replacement Brake Linings

The EPA has requested comments on the issue of the aftermarket for asbestos brakes. As GM has stated previously, brake friction materials are only one element of design which establishes brake system performance. Simply replacing asbestos with current non-asbestos materials would inevitably alter the performance of brake systems.

While used brake systems which have been serviced are not required by regulation to meet the same detailed performance requirements as new systems, GM practice has been to provide service components which substantially equal the performance of original equipment manufacturer [OEM] components. General Motors recommends the use of genuine GM replacement brake friction materials to assure acceptable performance after servicing. We believe that recent debates with the NHTSA regarding the performance of brakes on GM "X" cars and other vehicles have established that the characteristics of replacement materials should be substantially the same as OEM materials. While the EPA has correctly acknowledged that there are a multitude of replacement friction materials on the market, GM does not and cannot agree that these are fully acceptable as substitutes for its OEM materials as is suggested by merchandisers.

At the present time, General Motors markets brake system service kits containing asbestos friction materials for more than 100 brake applications. While the development of non-asbestos brake systems for original equipment is difficult, the development of non-asbestos friction materials for aftermarket use, particularly for systems which are no longer in production, can be expected to be even more difficult. It is GM practice to provide GM service kits with friction materials which are acceptable as direct replacements for OEM materials. Unfortunately, to General Motors knowledge no non-asbestos materials exist which would provide fully acceptable performance as direct replacements for OEM materials for many applications.

Alternately, such kits might be required to contain additional components, such as different wheel cylinders and/or proportioning valves, to compensate for any difference in the characteristics of the replacement friction materials. This alternative, however, is unlikely to be accepted in the replacement market. Customers often purchase non-OEM equivalent materials which may degrade the performance of the brake system. As important as all of these considerations are, the prospect of reengineering over 100 brake systems would be an enormous undertaking in and of itself. The challenge is made even more formidable in view of the fact that all available resources will be taxed to complete the similar task for OEM systems.

Vehicles that were designed to use friction materials containing asbestos clearly have finite lives and continued usage would naturally subside as these vehicles are retired from service. Rather than forcing GM and other OEM suppliers to consider discontinuing the practice of offering fully effective service kits, it is recommended that an exemption be provided so that vehicles having brake systems which were originally designed to use asbestos friction materials would be allowed to be serviced with asbestos. Such a strategy would also avoid the potential for undesirable changes in brake system performance.

Exemption Process

The EPA has suggested the possibility of establishing an exemption process at the end of the phase-down period but did not give details of the procedure for obtaining exemptions. If the EPA proceeds with this rulemaking, then GM believes that an exemption process is essential and must be established concurrently with any phase-down or staged ban regulations.

Immediate exemption will be needed for aftermarket replacement brake linings. As discussed above, GM believes that requiring the conversion of aftermarket asbestos brake friction material to non-asbestos would be infeasible as well as ill-advised.

Immediate exemption will also be needed for asbestos replacement gaskets for certain aircraft engines. The Allison Gas Turbine Operations of GM is a manufacturer of aircraft engines and industrial engines. Most of the high temperature (over 700° F) gaskets used in these engines contain asbestos. The task of validating non-asbestos gaskets for engines that were originally designed to use asbestos is impractical and unwarranted in light of the _de minimis_ health risk posed by this limited usage. As is the case for servicing past model vehicles, these aircraft engines will be retired at the end of their useful life, and the need for this exemption will disappear.

General Motors also believes that the exemption system must incorporate provisions for exempting brake systems for which no acceptable substitutes can be identified in time to meet the phase-down requirements for asbestos friction materials. While it can be expected that asbestos eventually can be eliminated from most brake applications, there is substantially less certainty that success will be realized for all passenger car and all truck applications (less than 23,000 lb. GAWR) within a 10 year period.

As mentioned earlier, there is currently no material available for converting to non-asbestos drum brake linings for certain heavy truck applications. Although GM is currently working with suppliers of brake systems who are pursuing solutions, the lack of viable candidate substitute materials makes it impossible to establish when a change can be implemented. As a result, GM urges the EPA to grant an exemption for trucks with GAWR's in excess of 23,000 pounds single and 46,000 pounds tandem so that the time which is essential to identify and validate substitutes is available.

Inasmuch as the details of an exemption system have not been proposed by the Agency, it is recommended that this matter be the subject of a supplementary notice of rulemaking so that interested parties will be afforded an opportunity to comment on and assist in its development.

Labeling

The EPA has requested comments on whether the labeling of asbestos products that are not subject to immediate ban should be required. The following comments will be limited to the appropriateness of labeling asbestos products on motor vehicles.

GM believes that the proposed direct labeling of all asbestos-containing parts on motor vehicles would be burdensome and in most cases of limited or no value. The smallness of size and hostile environments (e.g. immersed in fluids, high temperatures) in which some parts must operate would make the direct labeling of such asbestos-containing parts ineffective because the label would be promptly lost, defaced or destroyed. Similarly the location of some parts would render the warning labels ineffective. GM currently labels all containers of asbestos friction material replacement parts with a warning label using the language suggested in 29 CFR 1910.1001.

If the EPA concludes that the subject of labeling of asbestos products should be pursued further, then GM recommends that the EPA issue a supplementary notice of rulemaking that contains specific details of the proposal and allow sufficient time for affected parties to evaluate the viability and impact of any such proposal.

CONCLUSIONS

GM believes that there are serious questions about the necessity for the banning of all asbestos-containing brake friction materials. It is clear that the health risks associated with brake wear products is dramatically less than the risks estimated by the EPA. Given this, the health risk uncertainties associated with possible substitute materials, and the magnitude of the task of eliminating asbestos from brake applications, GM urges the Agency to reexamine its plans regarding this matter.

The questions of how and when all asbestos can be eliminated from all vehicle applications cannot be answered with any degree of certainty at this time. Substantial diversion of resources will be required to address the OEM passenger car and truck brake systems which currently employ asbestos. How long it will take to invent or identify, and to validate changes for all of these applications is subject to speculation. We also believe that it is impractical and unwise to pursue the elimination of asbestos from replacement friction materials for brake systems of past models which have been designed to use asbestos.

GM is certain, however, that the elimination of asbestos friction materials from OEM passenger cars, and OEM truck applications less than 23,000 pounds GAWR after a 10 year period is more practicable than the phase-down conditions of the EPA's proposal (permit system) or any of the EPA's suggested alternatives. GM is also certain that if a ban is to be required, immediate exemptions for heavy trucks (greater than 23,000 lb. GAWR), certain high temperature aircraft engine gaskets, and aftermarket brake linings will be required. The exemption system must also allow for the exemption of brake systems for which no acceptable substitutes can be identified in time to meet schedules for the elimination of asbestos friction materials. GM recommends that the EPA issue a supplemental notice of rulemaking that contains details of any proposed labeling requirements.

REFERENCES

Berry G. and Newhouse M.L., 1983 "Mortality of Workers Manufacturing Friction Materials Using Asbestos," British Journal of Industrial Medicine 40:1: 1-7.

Daniels R.J. and Roberts R.S., 1984 "Predicting Workplace Health Risks," in Appendix to Chapter 7 of Report of The Royal Commission on Matters of Health and Safety Arising from the Use of Asbestos in Ontario Toronto, Ontario, Ontario Ministry of the Attorney General, 1984.

Dement J.M. et al., 1982 "Estimates of Dose-Response for Respiratory Cancer Among Chrysotile Asbestos Textile Workers," Annals of Occupational Hygiene 26:1-4: 869-887.

McDonald J.C. et al., 1971 "Mortality in the Chrysotile Asbestos Mines and Mills of Quebec," Archives of Environmental Health 22: 677-686.

McDonald J.C. et al., 1980 "Dust Exposure and Mortality in Chrysotile Mining, 1910-75," British Journal of Industrial Medicine 37:11-24.

Enterline P.E., DeCoufle P., Henderson V.L., 1973 "Respiratory Cancer in Relation to Occupational Exposures Among Retired Asbestos Workers," British Journal of Industrial Medicine 30:1: 162-166.

Finkelstein M.M., 1983 "Mortality Among Employees of an Ontario Asbestos-Cement Factory," Toronto, Ontario Ministry of Labour, February 1983, revised September 1983.

Lee K.P., Kelly D.P., Kennedy G.L. Jr., 1983 "Pulmonary Response to Inhaled Kevlar Aramid Synthetic Fiber in Rats," Toxicology and Appl. Pharmacology, 71: 242-253.

Peto J., "Lung Cancer Mortality in Relation to Measured Dust Levels in an Asbestos Textile Factory," in Biological Effects of Mineral Fibres vol. 2 ed. J.C. Wagner, IARC Scientific Publications, no. 30, 1980, pp. 829-836.

Peto J. et al., 1977 "A Mortality Study Among Workers in an English Asbestos Factory," British Journal of Industrial Medicine 34: 169-173.

Selikoff I.J., Hammond E.C., Seidman H., 1979 "Mortality Experience of Insulation Workers in the United States and Canada, 1943-1976," Annals of the New York Academy of Sciences. 330: 91-116.

Williams R.L., Muhlbaier J.L., 1982 "Asbestos Brake Emissions," Environmental Science Dept., General Motors Research Laboratories, Warren, MI.

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January 13, 1986
USG 2456

Mr. Barry Felrice
Associate Administrator for Rulemaking
National Highway Traffic Safety Administration
400 Seventh Street SW
Washington, DC 20590

Dear Mr. Felrice:

The enclosed comments by General Motors respond to the Notice of Proposed Rulemaking (Docket No. 85-06; Notice 1) which proposes a new FMVSS 135 to replace the current FMVSS 105 as it applies to passenger cars. The stated intent of this action is to promote harmonization between US and worldwide brake standards. General Motors appreciates the efforts of the NHTSA toward harmonization, and in particular commends the agency for its strong representation and cooperative attitude which was evident at the special meeting of the GRRF in Dearborn during October, 1985, when this proposed standard was discussed at length by U.S., European, Japanese, and Canadian government and industry representatives. Nevertheless, as can be seen from reviewing the extensive new information and analysis contained in these comments, we are disappointed at the failure of Notice 1 to advance the cause of international harmonization.

The attached comments were distilled from what has been the most time consuming and extensive effort GM has ever undertaken in responding to NHTSA rulemaking. At least five and a half man-years have been devoted to the testing, analysis, and writing which are embodied in these comments. Additional data have been incorporated from test work done prior to the issuance of Notice 1. The results of this effort demonstrate that the harmonization goals have not been met and major revisions will be needed.

If there is one overriding fact that emerges from this test and analysis work it is this: the requirement that vehicles be front wheel skid limited during brake stops under practically all conditions has profound effects on nearly all of the other brake performance characteristics which are subject to regulation. It so dominates brake design and test performance that it is not proper to compare FMVSS 105 and the proposed standard by simply comparing stopping distances, as our attached detailed comments demonstrate. The effect of a front skid limited requirement is exacerbated by the incorporation of a vehicle test for this condition.

A second important observation from these studies is that current original equipment tires, under the influence of customer demand and Corporate Average Fuel Economy requirements, have lower tire to road traction coefficients than might generally be recognized. Thus a vehicle's braking performance under many of the test conditions regulated by the various brake standards is tire skid limited rather than brake system design limited.

The combination of front skid limited brake balance, the significant differences in test conditions between FMVSS 105 and the new proposal, and the effects of CAFE requirements on tire to road dry traction dictate that longer stopping distances than proposed in FMVSS 135 be allowed. We believe that our analysis contained herein makes it clear that the necessary longer stopping distances should not be considered a relaxation of FMVSS 105 but rather a different balance of requirements for the purpose of emphasizing yaw stability while minimizing stopping distance. The increased emphasis on brake balance carries with it an unavoidable need to increase stopping distances.

The change in emphasis is necessary to achieve harmonization with Europe, where front skid limited design has been a part of the regulations for years. (If NHTSA were to attempt to achieve harmonization through emphasis on shortest stopping distance rather than front skid limit, the European community would have to be convinced to change their approach.) While the method of implementation can be of concern, General Motors does not object to the change in emphasis, even though we do not believe that front bias is necessarily superior. Rather, we believe that effective brake systems can continue to be built if the new standards are appropriately written so that the brake designs are not forced to deviate far from having "ideal" balance.

In order to provide the freedom to design the best brake system under harmonized standards, FMVSS 135 should embody the following:

1) An approach to brake balance regulation that controls the nominal vehicle design rather than one that compromises the majority of vehicles by emphasizing the variability extreme; we recommend a calculation approach as is used in the European standards.

2) Correspondingly longer stopping distances than were proposed in Notice 1.
3) Allowance for brake system and tire traction variability.

Our general comments and attached appendices explain the reasons behind these and the many additional conclusions and recommendations which are provided. Of special note is Appendix 29 which details our engineering conclusions regarding the effect of the current proposal on brake system design.

GM has great reluctance about responding to NHTSA's request at the Dearborn meeting to provide actual recommended stopping distances. Although our test program and analysis have been extensive, at this time we can only estimate the margin needed between calculated minimum stopping distances and a realistic requirement that can encompass all of the reasonably expected vehicle-to-vehicle and tire-to-road traction variability, yet be constraining enough to assure good designs. Also, there are many test conditions yet to be settled, and achievable stopping distances are dependent upon them. Thus more work is necessary before we can arrive at a viable harmonized standard.

Since the purpose of the proposed standard is harmonization, our recommendations are based on the premise that the new standard should not require extensive changes to vehicles that currently meet FMVSS 105. The basic reason for harmonization is to ease the difficulty of designing a single vehicle to meet standards the world over. Therefore, our comments regarding performance levels are influenced by the desire to achieve a level of performance similar to that of FMVSS 105, rather than the more difficult situation of meeting both FMVSS 105 and the somewhat conflicting current European standards.

GM's comments do not include a comprehensive recommendation as to the specific elements which should comprise a final new standard; they do include detailed information regarding the interrelationships and constraints which must be comprehended by any final rule. This response recommends additional rulemaking action that will be needed to effect a viable final rule. Specifically, GM recommends a supplemental NPRM designed to obtain information needed to establish appropriate stopping distances for the various brake testing scenarios.

Finally, because of the complexity and seriousness of the brake issues, GM recommends meetings with agency management and rulemaking personnel to discuss in detail the comments contained herein.

We are, of course anxious that we not fail to convey adequately an understanding of our analysis. Accordingly, should you have any questions or wish to pursue any of the points in more detail, we will be happy to assist you. You can reach me at 313-575-1230, or contact Mr. Humphrey in our Washington office at 202-775-5071.

Sincerely,

David E. Martin

David E. Martin, Director
Automotive Safety Engineering

cc: Ms. Diane Steed, Administrator
Mr. Duane Perrin
Docket Room, Docket No. 85-06 (10)

January 13, 1986

USG 2456

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GENERAL MOTORS CORPORATION

RESPONSE TO

PROPOSED FMVSS 135 - PASSENGER CAR BRAKE SYSTEMS

DOCKET NO. 85-06, NOTICE 1

INTRODUCTION

Docket No. 85-06, Notice 1 contains the proposal from the National Highway Traffic Safety Administration for a new Federal Motor Vehicle Safety Standard No. 135 which is to apply to passenger car brake systems. This proposal is intended to reflect a stated commitment by the NHTSA to develop a new standard which will lead to the international harmonization of brake regulations.

The complexity of the issues, particularly the interrelationship of the requirements for brake balance and stopping distance, have resulted in a proposed FMVSS 135 that will not achieve harmonization. Our examination of the interrelated requirements of the standard in light of our new test data and analyses shows that the proposed requirements are not justified, nor required. The information that GM has developed in response to the proposal shows that major changes are needed since the vast majority of current technology vehicles cannot meet the proposed standard. As a result GM urges the agency either to proceed with a Supplementary Notice of Proposed Rulemaking reflecting consensus with industry comments to Notice 1 and with ECE WP 2916/GRRF and R.94 (herein referred to as R.88), or alternately, withdraw the FMVSS 135 proposal.

We recognize that the agency position as stated in the November 1, 1985 letter from Administrator Steed to the Docket "that there had not been any intent in drafting proposed FMVSS 135 to develop more stringent requirements." However, to achieve a harmonized standard without imposing greater stringency requires a proper blend of requirements, as well as a recognition of the capability of current technology brake systems. It is evident from studying Notice 1 that significant new information is needed for a viable new standard to emerge.

General Motors has made a major commitment of resources to develop the data and information contained in this response. A primary focus of the GM test program conducted for this response has been to quantify the performance of current technology brake systems. This information is provided in the attached appendices which have been identified in the Table of Contents. In the interest of providing an objective analysis, two "example vehicles" which are representative of current vehicle configurations as well as those to be marketed in the 1990's, have been used in the GM study (see Appendix 3, entitled "Example Vehicles"). One was a five passenger rear wheel drive (RWD) vehicle having a brake system with significant compliance margins relative to FMVSS 105 requirements. The other was a five passenger front wheel drive (FWD) car having a brake system designed to comply with both FMVSS 105 and ECE R13. Information regarding the above and other vehicles provides new and essential insights into the performance limits of current technology brake systems.

This response also includes General Motors responses to specific questions posed by the agency in the preamble to Notice 1 (see Appendix 31, entitled "Responses to NHTSA Questions").

Finally, General Motors has participated in the development of the comments which have been filed by the Motor Vehicle Manufacturers Association. The MVMA comments address a number of issues which are not covered in these GM comments. Where not inconsistent with this response, GM concurs with the MVMA comments and incorporates them herein by reference.

CONCLUSIONS

- The proposed FMVSS 135 is not a viable harmonized standard for at least three reasons:
    - It departs significantly from the compromise proposal developed by the GRRF.
    - It is a significantly and unnecessarily more stringent standard than either FMVSS 105 or ECE R13.
    - The combination of provisions specifically proposed cannot be met by current technology brake systems.
- The conclusions from the GM study of FMVSS 135 are detailed in Appendix 29, entitled "Summary of Engineering Conclusions".

RECOMMENDATIONS

- The next action in this rulemaking should not be a final rule, but rather be a Supplemental Notice of Proposed Rulemaking as discussed in Appendix 32, entitled "GM Recommended Approach".
- GM recommends that it meet with agency management to provide an overview of the comments contained in this response. Further, it is recommended that similar meetings be held with agency rulemaking personnel to review the GM comments in detail and to answer any questions which may arise.

DISCUSSION

The following sections summarize the information and findings which are detailed in the attached appendices.

HARMONIZATION

The attempt to develop a new harmonized brake standard for passenger cars is a worthwhile effort. The proposal is aimed at fulfilling the international commitment to achieving harmonization in governmental regulations and holds the potential to remove non-tariff trade barriers, as well as reducing design complexities, proliferations and attendant costs.

In the search for a harmonized brake standard, the challenge is to identify a set of common tests and performance requirements that are consistent with existing individual standards. While it is predictable that the differences of opinion among interested parties will make the development difficult, the worldwide benefits clearly make the task worthwhile.

In the Preamble to Notice 1 the agency has acknowledged that this rulemaking grew out of the process of assessing the current effectiveness of and necessity for each FMVSS. Further, the agency cited its work "with international standards bodies to revise some of its standards through the harmonization process". These comments and those made by the NHTSA Administrator during the October GRRF meeting have established that this rulemaking action is not motivated by a safety need not being addressed by the current standard. No case has been advanced that there is a safety need to modify FMVSS 105. General Motors is also unaware of any such safety need.

International Consensus - An international harmonized standard for passenger car brakes can be realized only to the extent that international consensus on the many provisions can be reached. While FMVSS 135 incorporates procedures similar to document R.88, it also contains many other fundamentally different provisions and requirements. For example, the NHTSA has proposed preburnish effectiveness, a different burnish schedule, new fade heating sequences, a post fade "over-recovery" limit, a different hand brake apply force limit, a requirement for automatic adjusters, spike stops, and a vehicle test for adhesion utilization. In developing an amended FMVSS 135 proposal, the NHTSA is urged to comprehend the extensive effort and spirit of accommodation which led to R.88. The pursuit of harmonization should be guided by the premise that brake systems complying with the resulting regulation should be acceptable for use in all jurisdictions.

Unnecessary Requirements Should Be Dropped - The proposed FMVSS 135 contains a number of test procedure provisions different and/or in addition to those contained in the draft standard developed by the GRRF as well as FMVSS 105. In several cases these differences are unnecessary and have the potential for jeopardizing harmonization.

In developing the proposed FMVSS 135, the NHTSA has decided that water recovery no longer needs to be regulated, and therefore accepted the GRRF proposal to delete such requirements. There are several other requirements, notably spike stops, final effectiveness and the preburnish provisions which need not be retained because there is no safety need. Their deletion would also promote harmonization. Specific proposals regarding these matters are included in later sections of these comments.

EQUIVALENCY

The matter of assessing equivalency between FMVSS 105 and FMVSS 135 is made particularly difficult by the different emphasis of the two standards. The proposed standard adopts the European emphasis on stability during a stop. As a result, an assessment of equivalency on the basis of comparing performance for individual provisions, requirement by requirement, is inappropriate. The agency has acknowledged this concern in its Final Report DOT HS 806 752 where it stated: "A direct comparison of the requirements on similar tests is not possible since the tests are run at different speeds, different pedal force limits, different number of stops in a test sequence, different lockup criteria, and with different amounts of conditioning prior to any one test sequence".

Variability Must Be Comprehended - Discussions of equivalency and stringency must deal with variability. NHTSA attempted to analyze equivalency by using stopping distance margins achieved during FMVSS 105 testing to develop performance levels for FMVSS 135. This approach is inappropriate because it does not address a concern which is fundamental to harmonization. To reduce the disadvantages associated with product proliferation, General Motors has, for some of its vehicles, designed brakes which perform within the narrow "window" of overlap between FMVSS 105 and ECE R13. This has resulted in smaller margins of compliance than could be achieved if only FMVSS 105 was the target. Basing new requirements on these smaller margins, which are not achievable for many vehicle families, negates any potential for deproliferation, one of the major purposes of harmonization. Neither customers, the agency nor manufacturers are served well if the allowance for variability in the requirements is so small that meaningless noncompliances occur, particularly if they lead to unnecessary recalls.

Passenger car brake systems exhibit variability in performance during FMVSS testing as a result of many factors. These include vehicle loading conditions, the inherent properties of brake friction materials, temperature of brake components and the degree of burnish. Vehicle loading introduces variability because each brake configuration must perform for a variety of vehicle option configurations, since it is impractical to tailor a unique brake system for each specific vehicle. The remaining factors relate to variabilities which exist within the brakes as a result of the manufacturing and composition of the components. The rigorous application of quality control practices can minimize manufacturing differences, but a major portion of the variability is attributable to factors which are not related to production. In addition, the performance variabilities that can be anticipated for brake balance, stopping distance capability, and fade, as well as the variablilities anticipated for other regulated and nonregulated aspects of performance, are interrelated.

Much of the GM analysis in these comments reflects minimum theoretical stopping distances plus an additional allowance for variability. What variability allowance should be included in the final standard will depend on the specific test protocol and requirements which are adopted, as discussed in Appendix 12, entitled "Variability".

For purposes of this response, General Motors studied variability for a number of vehicles which were conditioned with a burnish schedule of 200 stops. The GM study established that the minimum range of variability for brake balance under these optimum conditions is 10 percentage points. The resulting increases in stopping distances for various balance assumptions and vehicle configurations range from 4.5% to 11% beyond the theoretical minimums achievable based upon calculations. A further increase in stopping distance is inevitable when the certification protocol requires that every vehicle be capable of exhibiting front bias using a physical test. This occurs because the nominal vehicle in a family must be significantly more front biased for a manufacturer to be assured that all vehicles in that family are front biased. While the above provides important insights, the effects of variability on stopping distances cannot be quantified until the method of demonstrating brake balance compliance within FMVSS 135 is established.

STRINGENCY

General Motors believes that because the agency does not intend to increase stringency, any vehicle which can currently meet both FMVSS 105 and ECE R13 with the same brake system should not have to be redesigned as a result of the adoption of a new standard. However, the new standard must eliminate the design constraints imposed by the narrow overlap of the existing regulations. This entails blending the requirements of both standards, as was attempted in ECE R.88.

Brake Balance has a Dominant Effect - A major change in emphasis in FMVSS 135 vs. FMVSS 105 involves brake balance. This provision combined with the many sources of variability in performance, has a much more pronounced effect on brake design than is generally understood. The proposed provision in FMVSS 135 that every car be capable of exhibiting the prescribed balance during a physical test has the inevitable effect of dictating that stopping distances be increased from the levels of FMVSS 105.

To quantify the trade-off between stopping distance and brake balance, GM has computed the performance for the example car configurations using various assumptions. The first order results included in Appendix 4, entitled "Brake Balance Influence on Stopping Distance", illustrate the stopping distance performance which would be achievable if the FMVSS 135 brake balance requirements were adopted. The effects on stopping distances are shown for both front wheel or rear wheel drive configurations and for verification by calculation or physical test. The influences discussed in Appendix 4 do not account for performance variability, a factor which can only further increase achievable stopping distances. The calculations serve to illustrate the analytical methods which can be used to further develop FMVSS 135 stopping distance requirements, once the effects of variability have been quantified.

Self Certification Demands More - Self certification for any brake standard is more demanding than ECE Type Approval certification. In the US a manufacturer is required to certify that 100% of production meets the requirements. This constraint dictates that every reasonable effort be made to assure that product variabilities be comprehended within the certification. What precludes a manufacturer from building vehicles which comply with the requirements with a large compliance margin to accommodate variability? This strategy is simply not viable because of the boundary conditions which are imposed by vehicle design constraints, laws of physics, material limitations and conflicting regulations such as those involving fuel economy. For example, as is detailed in Appendix 7, entitled "Tire Design Considerations", the US fuel economy regulations prompt the use of low rolling resistance tires while brake standards prompt the use of high traction tires. These are conflicting requirements. The solution does not lie in simply increasing the degree of quality control, as suggested by the agency, but in recognizing such constraints while the standard is being developed. The blend of requirements selected must reflect the braking performance which is available from current technology brake systems and assure the best performance for the largest number of vehicles.

Current Brake Systems Will Not Comply with FMVSS 135 - In the Preamble to Notice 1, the agency has made reference to testing which it has performed to examine the ability of current production vehicles to meet FMVSS 135. In various instances comments were made indicating that a sizable percentage of vehicles tested met some specific requirements. These experiences are viewed by the agency as being indicative of the ability of current vehicles to comply with the proposed FMVSS 135 in the "as is" condition or with only minor modifications.

As stated in the Appendix 14, entitled "NHTSA Tests", the GM study has established that because of observed vehicle performance or departures from the procedure in Notice 1, no vehicles tested by the agency met all of the FMVSS 135 requirements. Basing an evaluation on the performance of cars having some degree of rear bias, as well as using incorrect test procedures, limits the usefulness of the agency test results.

General Motors testing has shown that most vehicles in our current fleet would not comply with FMVSS 135. Only one of the seven vehicle configurations tested by GM met all of the proposed requirements as discussed in Appendix 8, entitled "GM Test

Program". These findings reflect only empirical data for the specific vehicles which were tested. Variability which is inherent in each family of vehicles would inevitably lead to further incidents of nonconformance. The inescapable conclusion from these findings is that few current brake systems can meet the proposed FMVSS 135. While it is possible to change proportioning valves to meet the proposed front bias intent, such a change will increase the stopping distances as discussed in Appendix 8.

The brake system reaction times which are reflected in Notice 1 are significantly shorter than those which GM has measured during its testing. This causes the agency calculations of stopping distances to be correspondingly shorter than is achievable. This subject is discussed in detail in Appendix 9, entitled "Brake System Reaction Time".

FMVSS 135 is a Major Change - Contrary to the views cited in the Regulatory Evaluation of FMVSS 135 performed by the agency, GM has found the proposed rulemaking to be major as defined in Executive Order 12291 and significant within the meaning of the Department of Transportation regulatory policies and procedures. Any proposal which includes brake performance requirements that have not been demonstrated as achievable, given acknowledged product and test variabilities, is both major and significant.

The cost to meet FMVSS 135, even if possible with new technology, would be substantial. In light of these considerations, General Motors has not developed specific cost or leadtime information. GM recommends that the agency retract its proposed effective date of September 1, 1991 and postpone any determination on the matters of cost and leadtime until the provisions of FMVSS 135 more nearly reflect an international consensus.

STOPPING DISTANCE & YAW CONTROL vs YAW STABILITY

In the FMVSS 135 Regulatory Evaluation, the agency emphasizes the importance of stopping distance to automotive safety. FMVSS 105 places dominant emphasis on stopping distance and minimal focus on brake balance. ECE R13 places stronger emphasis on brake balance and accordingly lessens the emphasis on stopping distance. Short stopping distances and the retention of steering control contribute importantly to accident avoidance potential and the reduction of impact speeds. Emphasis on short stopping distances dictates substantial rear braking, which translates to rear bias at high deceleration rates and lightly loaded vehicle conditions for conventional vehicles. Rear bias may provide the driver with a useful cue, in the form of yaw acceleration, to begin modulating his brakes to maintain path control. Emphasis on front bias yields vehicles that generally have a reduced tendency to yaw in some braking maneuvers. The benefits claimed for front bias is that there is a reduced need to maintain directional control in straight line braking. Thus, an emphasis on front biased brake balance relies upon a perception that frontal impacts which might occur due to longer stopping distances are preferred over impacts which might occur due to loss of yaw control. Both views necessarily represent oversimplifications of very complex and interrelated factors. Requiring vehicles to be front axle limited is no guarantee that yaw displacement will not occur within some accident scenarios.

Many braking experts believe that the safety of brake systems depends on short stopping distances. Other experts believe with equal fervor that yaw stability, which is normally associated with front bias, is fundamental to safety. The emphasis in ECE R13 calls for the nominal vehicle to be front axle limited under the specified conditions. FMVSS 135, which prescribes the benefits of both short stopping distances and front bias, cannot be met without incurring the expense of higher technology brake systems such as those incorporating an expensive four wheel anti-lock feature. A more reasonable solution would be to place more emphasis on brake balance, e. g. front bias, while also recognizing the reality of increased stopping distances. Requiring front bias with attendant longer stopping distance provisions does not constitute a relaxation of stringency, but rather a change in emphasis. Vehicles with conventional brake systems can be built to comply with a regulation which calls for either front or rear bias as long as the stopping distance requirements are set appropriately. The challenge for the agency, manufacturers and interested parties is to assure that the final trade-off is truly responsive to real world safety needs.

A Trade-Off Is Necessary - Appendix 2, entitled "Derivation of Brake Balance Representations", provides a detailed derivation of the brake balance relationships and several formats to display these characteristics. Appendix 4 provides a quantitative assessment of the influences on stopping distance performance which are attributable to varied conditions such as the magnitude and direction of bias, peak tire-to-road coefficient, brake system reaction time, and vehicle parameters. The insights provided by these two Appendices are important to identifying a blend of provisions to assure a viable standard. In the Administrator's November 1, 1985 letter cited above, an agency representative at the October GRRF meeting was quoted as follows: "a tradeoff between stopping distance and stability was unnecessary since the proposed requirements are short of the theoretical limits where such problems might occur." The GM study of these issues has established that this view is erroneous.

TIRES

Tire-to-Road Coefficient - Test road surface characteristics play an important role in determining vehicle stopping distance since the tire design and road surface are interactive in generating peak traction during braking. There are no widely accepted methods for separately measuring the contribution of the road to braking traction, independent from that of the tire. As detailed in Appendix 6, entitled "Tire to Road Coefficients", the peak traction occurs at about 10% slip rather than 100% slip (locked wheel) as specified within FMVSS 105. In addition, the current ASTM control tire configuration is an obsolete design which was established in the 1960's. GM recommends that the new

ASTM control tire discussed in Appendix 6 be adopted for inclusion in FMVSS 135 and that consideration be given to defining the road surface statistically, based on peak rather than sliding traction. GM recommends that the agency collaborate with vehicle, tire and road interests in developing an effective methodology for quantifying the road's contribution to traction and associated vehicle stopping performance.

<u>Tire Burnishing</u> - Recent experience has confirmed that a relatively large increase in dry traction occurs as tires evolve from a "green" or new condition to a fully burnished condition. While the magnitude and rate of change are dependent on tire design and usage, the GM data indicate that new original equipment tires exhibit a peak dry coefficient as low as 0.7, a value which increases to a maximum of about 0.9 as the tires continue to burnish through the FMVSS certification test. The rate of increase has been shown to be more directly related to accumulated braking than mileage. While all of the causes have not been isolated, important contributors may include the initial presence of mold release compounds, oils and mold vents. Rear tires typically contribute less to stopping a vehicle and this results in the rear tires burnishing more slowly than the fronts. The effects of these characteristics combine to yield varying front-to-rear tire traction balance and an increasing stopping ability as tire burnish progresses. Appendix 11, entitled "Tire Burnish", provides further important detail on this matter.

<u>Tire Design</u> - As discussed in Appendix 7, entitled "Tire Design Considerations", tires have a major influence on stopping ability of vehicles since tire-to-road peak traction limits the level of deceleration which is attainable before tire slide occurs. During FMVSS 105 certification testing and while evaluating FMVSS 135, General Motors has observed that the braking capability of vehicles is frequently tire traction limited as well as brake limited. This trend has been attributed to the gradual reduction in peak traction of original equipment tires as manufacturers have responded to customer demands for greater fuel economy, improved wet and snow traction, and increased tread life. Tires have been optimized for dry, wet and snow traction as well as tread wear, noise and rolling resistance. Current tire technology does not allow a substantial increase in peak dry coefficient without incurring unacceptable increases in rolling resistance or reduced tread life. Based on its 100 km/hr (62 mph) stopping distance test data, GM has determined that a reduction in stopping distance of 3.75 m (12.5 feet) will require an increase in peak traction coefficient of 0.10. The resultant increase in rolling resistance would decrease vehicle fuel economy about 1.0 mpg for a vehicle rated at 25 mpg. For a vehicle rated at 40 mpg, the mpg penalty nearly doubles.

<u>BURNISH</u>

<u>Preburnish Requirements Must be Changed or Deleted</u> - Experience has established that the FMVSS 105 preburnish requirements are more difficult to meet than those which apply to burnished brakes. When new, the "unconditioned" linings, pads and tires have uncertain and changing characteristics. As a result, brake

engineers select brake output and balance parameters which compensate for the limited predictability of preburnish characteristics. The data contained in Appendix 16, entitled Pre-Burnished Brake Effectiveness", show that this practice results in longer post-burnish stopping distances than if design decisions were guided by the burnished brake performance considerations. We believe that FMVSS 135 should be changed to allow brake designers to maximize performance for the condition which exists for the vast majority of brake life, i.e. the burnished condition.

Handling of Preburnish Requirements - As shown in Appendix 16 and Appendix 10, entitled "Brake Burnish", stringent green brake and tire performance requirements can result in compromised vehicle designs. Further, it is General Motors view that preburnish effectiveness requirements are unnecessary and an impediment to harmonization. Significantly, the European community has successfully operated under a regulation without such requirements for many years. Therefore, it is recommended that the preburnish effectiveness requirements be eliminated.

Brake Balance Changes Significantly with Burnish - Most domestic brake designs incorporate front disc brakes using semi-metallic pads and rear drum brakes using asbestos linings. During burnish, these friction materials undergo significant change, including becoming more consistent. However, their coefficients of friction change in opposite directions. The rear asbestos lined drum brakes can decrease in output approximately 40% and the front "semi-met" disc brakes can increase in output up to 40% from start to finish of burnishing. These transformations result in the brake balance changing from the "green" or preburnished condition to the burnished condition. The change in friction material properties as a result of burnishing makes it essential that the FMVSS burnish schedule be sufficiently long to assure consistent performance.

General Motors study of burnish which is detailed in Appendix 10 has established that a significantly longer burnish schedule than that proposed in FMVSS 135 is essential to meaningful FMVSS stopping distance performance evaluations. The GM study of burnish has led to the conclusion that a burnish schedule such as that prescribed in FMVSS 105 is important to effective conditioning of brake systems and tires.

ADHESION UTILIZATION

FMVSS 135 proposes that passenger car front brakes lock up before the rears for all deceleration rates between 0.15g and 0.8g, with a specific limit on front bias set to correspond with that of ECE R13 and R.88. In addition, a physical test is specified as the method of establishing compliance of the brake balance of individual vehicles.

It is apparent that the GRRF and NHTSA are of the view that front brake bias is important to effective passenger car brake system performance. It is General Motors view that front bias is neither essential nor necessarily preferable over rear bias. GM believes that effective brake systems can be either front or rear biased provided that the deviation in either direction from ideal brake balance is not great. Any departure from ideal balance inevitably results in increased stopping distances. A consensus must be reached as to the trade-off between these performance considerations which best meets the need for motor vehicle safety.

The available accident data, cited by the agency in its Regulatory Evaluation, suggest a strong correlation between stopping distance and accident rates. Human factors tests have shown that typical drivers are able to achieve shorter stopping distances with rear axle limited brake balance than with front bias. Likewise, the European community has driven automobiles which comply with ECE R13 for many years, a regulation which permits rear bias under some circumstances, yet the GRRF has not suggested any need for a change in brake balance in its regulation.

General Motors study of Notice 1 has established that the combination of the proposed adhesion utilization requirement together with the aggressive stopping distance requirements cannot be met by the current vehicle fleet. GM believes that this will be true for vehicles produced by other manufacturers as well. The difficulty stems from the shift in brake balance which occurs due to changes from GVW to LLVW loading plus the variability in balance among vehicles. These changes are greater than the range of brake balances which are permitted in Notice 1. To require that all vehicles must be front biased means that the worst case combination of all tolerance stackups, option contents, loading conditions, friction material variations, proportioning valve characteristics and all other variables must be comprehended when the required stopping distances are established. Further, the acceptability of rear bias is affirmed by the fact that many of the production vehicles which are operating safely on the public roads, exhibit such bias under some conditions (see Appendix 12, entitled "Variability").

<u>Brake Balance Certification</u> - In settling on a certification protocol within FMVSS 135 for brake balance, it is essential that the impact on stopping distance performance be fully comprehended. A viable approach to assuring acceptable brake balance is to use the calculation methodology specified in ECE R13 and R.88. This method has been in use for several years outside of the United States and has been found to be effective by both manufacturers and regulators. It places constraints on balance, and in concert with other provisions, provides assurance that brake systems will perform acceptably in the hands of customers.

In Notice 1, the agency has proposed a physical test which all vehicles must be capable of passing. For purposes of this response, this test has been entitled "single axle procedure". As discussed in Appendix 13, entitled "Adhesion Utilization Assessment Tests", this procedure is technically feasible, but has several shortcomings which prompt GM to recommend that it not be used as a part of FMVSS 135. This procedure poses many opportunities for error in data acquisition and calls for measurements to be taken at only one deceleration level. These characteristics can result in inaccurate overall balance determinations. Appendix 13 also provides a discussion of other physical test methods using a Road Transducer Pad facility, torque wheels, and a Swedish skid test. In addition, an approach using a four wheel brake dynamometer was demonstrated for the GRRF during their meeting at the GM Proving Ground in October, 1985. It is conceivable that some new test together with appropriate tolerances accommodating current designs could eventually be developed. Each of these approaches has its advantages and disadvantages, but the lack of consensus indicates that much time consuming work remains to be done before any one test approach would be universally acceptable, whereas the calculation methodology is already developed. In addition to the impact on stopping distance, General Motors is also concerned that the pursuit of a physical test for brake balance must proceed with great care because such an approach is in conflict with ECE R13 and R.88 and poses a threat to harmonization.

FADE & RECOVERY PERFORMANCE

Fade Heating Cycles - In the Preamble of Notice 1 and the Regulatory Evaluation, the agency has addressed the matter of stringency of the heating cycle on the basis of brake peak temperature, a vehicle response parameter. The effective assessment of fade heating cycles depends upon using a methodology which quantifies the input conditions, not the thermal response of particular brake systems. It is more appropriate for a regulation to specify a cycle on the basis of customer need. As detailed in Appendix 25, entitled "Fade Heating Cycles", GM has evaluated several heating cycles on the basis of kinetic energy input as well as the resulting brake temperature and has shown the energy input provides a far more meaningful comparison. On this basis, it is shown that the R.88 cycle is more representative of real world customer demands and that both alternatives of FMVSS 135 are inappropriately severe.

Hot Stop Performance - In the interest of harmonization, GM acknowledges that a hot stop provision may be a necessary part of the standard. However, as is discussed in Appendix 26, entitled "Fade Hot Stop Tests", the proposed FMVSS 135 requirements are significantly more stringent than the performance needed to meet FMVSS 105, ECE R13 or R.88. The GM study has established that few vehicles without four wheel anti-lock can be expected to meet the proposed FMVSS 135 hot stop requirements. This is primarily a result of the combined influences of pedal force constraints and the requirement for minimal degradation in stopping effectiveness.

The GM study of the hot stop proposal has led to the recommendation that the pedal force limit be set at 500N (112 lbs.), not at a level derived from the cold effectiveness performance test. The hot brake performance would be satisfactory under these conditions since a driver would be expected to utilize his full force capability, not some lower level established earlier in the test sequence.

<u>Post-Fade Recovery</u> - The FMVSS 135 post-fade recovery requirements are significantly more stringent than those of FMVSS 105. The proposal prohibits any increase in front brake output as a result of exposure to the fade heating cycle. As discussed in Appendix 27, entitled "Post-Fade Recovery Effectiveness", it is recommended that baseline stops be conducted at the start of the fade and recovery sequence to establish a reference level reflective of the brake conditioning immediately prior to the fade and recovery sequence. It is essential that the heating cycle as well as recovery pedal force limits be revisited as a prelude to refining the post-fade recovery requirements. Appendix 27 provides further important detail on these matters.

<u>ANTI-LOCK & VARIABLE PROPORTIONING</u>

FMVSS 135 contains provisions for the performance of failed anti-lock and variable proportioning valves which are significantly more stringent than those of FMVSS 105, ECE R13 or R.88. General Motors is concerned that this situation raises several serious concerns as discussed in Appendix 22, entitled Failed "Anti-lock Requirements" and Appendix 23, entitled "Failed Variable Proportioning Systems".

In the interest of harmonization, it is essential that the level of performance be no more stringent than that of FMVSS 105; recognizing that even this stringency is more demanding than R13 or R.88 and therefore may not be internationally acceptable. Failures of these components are no more or less serious than failures of other elements of a brake system and all should be subject to the same failed system requirements. It follows that a reduced stopping ability which is deemed adequate to meet the need of motor vehicle safety for one failure mode is clearly adequate for all failure modes. The proposed requirements would deter the introduction of this technology; inasmuch as vehicles so equipped would be required to perform almost as well with the devices failed as with them functional.

GM supports the intent of the proposal in defining the nature of the system failures which are to be subject to the performance requirements. It is recommended that the failure modes of anti-lock and variable proportioning systems be addressed in separate sections of the standard, and reflect the differing designs and functions of these units.

<u>SUMMARY</u>

The General Motors test and analysis contained within the Appendices to this response show that the proposed FMVSS 135 is a significantly more stringent regulation than FMVSS 105 or ECE R13 and as a result does not constitute a viable proposal which will contribute to harmonization. The GM response shows that major changes in procedures and requirements are needed to bring the conflicting provisions of FMVSS 135 in line with the performance capabilities of current technology brake systems. GM looks forward to contributing to this process which is needed to yield an internationally harmonized braking standard.

GLOSSARY

ADHESION UTILIZATION - The longitudinal (brake) force divided by the vertical force at each wheel.

ANTI-LOCK BRAKE SYSTEM - A closed loop control system designed to prevent wheel lockup during brake application. This is typically accomplished by transducers for sensing wheel rotation and an actuation system under control of a computer that limits wheel slip under a variety of road surface conditions.

AUTOMATIC ADJUSTER - A mechanism for automatically compensating for lining wear in a brake system so that brake pedal travel is consistent from a new to a worn condition.

BOOSTER RUNOUT - A condition where the system intended to supplement driver brake application forces has achieved its maximum assist capability and increased forces must be applied solely by the driver.

BRAKE BALANCE - A general term used to describe the distribution of brake forces among the wheels of a vehicle. A "balanced" brake system maintains a distribution of brake force that is proportional to the distribution of vertical forces that prevail as the vehicle decelerates. A "front biased" or "front axle limited" vehicle will exhibit a higher ratio of front brake force to front wheel vertical force than the ratio of rear brake force to rear wheel vertical force, i. e. the front wheels will lock first when a brake force sufficient to cause wheel lock is applied. A "rear biased" or "rear biased limited" are the converse.

BRAKE EFFICIENCY - The ratio of maximum steady state deceleration without wheel lockup divided by peak tire-road coefficient of friction.

BURNISH - A procedure applied to new or rebuilt brake systems to condition the friction material and achieve a degree of friction material to disc or drum contact that approaches design intent. Burnishing is often achieved with an extensive series of low energy applications of the brake system or through typical vehicle service. The "burnished" condition is most representative of customer usage for the life of the brake components. It is also the condition where brake performance is typically most consistent.

CONTROL TIRE - A special purpose reference tire used by highway, tire, and vehicle engineers for testing purposes. Control tires are intended to provide a stable frictional reference that is relatively more consistent over time and among samples of the control tire design.

CURRENT BRAKE SYSTEM- A brake system with the following typical components: Semi metallic front disc foundation brakes, asbestos lined rear drum foundation brakes of duo servo or leading/trailing design, front/rear or diagonal split master cylinder and hydraulic apply systems, two slope fixed proportioning valve, vacuum power assist, open loop pedal force/braking force transfer relationship, low rolling resistance "Mud and Snow" designated tires with premium tread depth specification, and a mechanically actuated park brake with foot or hand apply system applied to the drum rear foundation brake.

FADE - A reduction in foundation brake effectiveness associated with high levels of energy dissipation in the brake system and resulting high temperatures. The reduced brake output, per applied brake line pressure, is typically associated with changes in friction material properties and may also be due to dimensional changes in some brake components.

FOUNDATION BRAKES - A general term used to describe the brake mechanism located in the wheel area of a vehicle. This term is used to differentiate "foundation brake system" components from "apply system" components such as booster, master cylinder and other parts not located in the wheel area.

FISHBONE CURVE - One of many methods for expressing objective brake balance data in graphical form. Most commonly, percent rear brake force is plotted as a function of deceleration.

FOUR WHEEL BRAKE DYNAMOMETER - A laboratory test machine capable of measuring brake forces at each wheel of a test vehicle during application at speed. This is accomplished by a system of rollers under each tire that are all geared to a common shaft and inertia weight system. The device simulates a road test situation and is intended for testing of a complete car.

FRONT BIASED/FRONT BIAS LIMITED - (See Brake Balance)

GREEN BRAKES/TIRES - New brake components or tires that have not been conditioned (burnished) to develop their more typical level of friction capability.

MANUAL BRAKE SYSTEM - A vehicle brake system where all actuating force is derived from the driver without assistance from other vacuum, hydraulic or electric power sources.

MOLD RELEASE COMPOUND - A substance sprayed in a tire molding machine prior to insertion of a uncured (raw) tire to assist in releasing the cured tire from the mold without tearing or other damage to the tread configuration.

OVER-RECOVERY - An increase in brake effectiveness after a high temperature fade test where the recovery effectiveness is greater than the level that existed prior to the fade test.

PASS MARGIN - The difference between the theoretical minimum achievable performance for a specific vehicle configuration and the requirement specified by a standard.

PEAK TIRE-ROAD COEFFICIENT - The maximum tractive force generated by a braked tire divided by its vertical force. Typically, the maximum tractive force can be observed while the tire is still rolling.

PREBURNISH - The state of new brake components or tires before any burnishing stops have been experienced (Also referred as "green").

RAMP APPLY - A brake test procedure where the driver applies a steadily increasing level of brake force so that the relative effectiveness of the elements of the brake system can be determined in a quasi-steady state condition.

REACTION TIME - A time delay interval required for the brake system to respond to an apply force; established by comparing time-history recordings of driver or machine applied pedal force and resulting vehicle brake torque or deceleration.

ROAD TRANSDUCER PAD (RTP) - A facility for making objective measurements of brake balance during a road test. A special section of road is supported on force transducers that measure longitudinal force and vertical force for all wheels of a car passing over the system with its brakes applied. Since all of the instrumentation is installed in the road, the test is adaptable to measurement of statistical populations of vehicles without modification or installation of special equipment on the vehicles.

SINGLE AXLE PROCEDURE - An approach to determine brake balance where brake force is calculated from observations of vehicle deceleration using only front or only rear brakes. The test vehicle must be modified so that the brake system on each axle can be disabled for test purposes.

SKID NUMBER - A term typically applied to measurements of sliding coefficient of friction for road surfaces using control tires. A skid number is the sliding friction coefficient multiplied by 100.

SLIDING TRACTION - Longitudinal force applied by a non-rolling tire sliding on a road surface.

SLIP (Longitudinal Slip/Percent Slip) - The difference between the spin velocity of a braked or accelerating tire and that of a free rolling tire for a particular vehicle speed. Percent slip is the ratio of the spin velocity of the braked tire to that of a free rolling tire, expressed as a percent, i.e. 0% slip describes an unbraked tire and 100% slip describes a sliding or locked tire.

SYSTEM REACTION TIME - (See Reaction Time)

TIRE TRACTION BALANCE - A condition where front and rear tires may not provide the same peak or slide friction performance on a given road surface due to differences in their design, burnish condition, or exposure to road contamination and vertical forces.

VARIABLE PROPORTIONER - Devices used to compensate brake balance for variations in vehicle loading. Typically they are hydraulic valves that sense changes in rear suspension trim height or changes in pressure for a height control system. The valves tend to increase rear brake system Line pressure as payload is added to the rear of a vehicle.

YAW - Angular motion of a vehicle about a vertical axis through its center of gravity.

YAW CONTROL - The ability of the driver-vehicle-road system to achieve the driver's yaw motion objectives during the driving task.

YAW STABILITY (INSTABILITY) - The magnitude of yaw motions associated with a particular maneuver. The term can be applied to a closed loop driving task where the driver-vehicle-road system may or may not be able to avoid yaw motions that are much larger than intended (instability). The term is more often applied to an open loop task where large yaw motions may be observed without the presence of appropriate driver control action (open loop instability).

BRAKE BALANCE REPRESENTATION

OBJECTIVE:

The purpose of this Appendix is to explain the development of the common forms of vehicle brake balance representation including the "Fishbone", Deviation from Ideal, Normalized Brake Efficiency, and Adhesion Utilization Diagram. This Appendix is intended to provide an understanding of our analysis in the other Appendices of this response.

DISCUSSION:

The Adhesion Utilization format has been used by the NHTSA in specifying brake balance requirements in FMVSS 135. The Fishbone and Brake efficiency formats are used by General Motors in various Appendices. All of the methods essentially provide the same information with respect to a vehicle's brake balance and they can be considered to be interchangeable. However, the Fishbone and the Normalized Efficiency format facilitate prediction of the maximum deceleration attainable for any loading condition at any tire to road coefficient of friction. Using these two formats, the brake balance performance of various brake configurations and loading conditions can be compared easily with only one curve per configuration rather than two per configuration required by the Adhesion Utilization format.

Derivation of Brake Balance Equations:

Figure 1 is a simplified diagram of a vehicle undergoing straight line braking on a level road. The symbols contained in that figure form the basis of all mathematical derivations in this Appendix and are defined, as follows:

W = Weight of the vehicle

CG = Center of gravity

h = Height of CG above the road

a = Position of CG behind front axle

b = " " " ahead of rear axle

(a+b) = Wheelbase.

V_f = Vertical force acting at the front axle

V_r = Vertical force acting at the rear axle

H_f = Horizontal force acting at the front axle

H_r = Horizontal force acting at the rear axle

A = Vehicle deceleration in g's

u = Tire-road peak traction coefficient of friction

L = Limit of adhesion

V'_f = Vertical force on the front axle when A = 0

V'_r = Vertical force on the rear axle when A = 0

R_r = Fraction of total braking done by the rear axle brakes, referred to as fraction rear braking.

R_4 = Fraction rear braking at ideal brake balance

All brake efficiency computations are based on the brake system related parameters for an FWD vehicle set forth in Table 1 of Appendix 3 , Example Vehicles.

Derivation of Equation for ideal balance:

When $A = 0$,

$$a\ V'_f = b\ V'_r \quad (1)$$

$$V'_f = (b/a)\ V'_r \quad (2)$$

and,

$$V'_f + V'_r = W \quad (3)$$

Taking moments at the rear tire contact point,

$$V'_f\ (a + b) = W\ b$$

Therefore,

$$V'_f = W\ b/(a + b); \text{ and } V'_r = W\ a/(a + b) \quad (3a)$$

When $A > 0$

$$H_f + H_r = A\ W \quad (4)$$

Taking moments at rear tire contact point,

$$A\ W\ h + W\ b = V_f\ (a + b) \quad (5)$$

or

$$V_f = (A\ W\ h + W\ b)/(a + b) \quad (6)$$

and,

$$V_f/W = (b + A\ h)/(a + b) \qquad (7)$$

Similarly, by taking moment at the front axle contact point, it can be shown that,

$$V_r/W = (a - A\ h)/(a + b) \qquad (7a)$$

Comparing 3a, 7 and 7a suggests that the 'force transfer'(T), from the rear to front axle due to deceleration is given by,

$$T = A\ W\ h\ /(a + b) \qquad (8)$$

Equation for condition at ideal brake balance:

At ideal brake balance, the braking forces at each axle are equal to the limit of adhesion at each axle, where the limit of adhesion is given by,

$$L = u\ V \qquad (9)$$

where,

- L = Limit of adhesion on a given axle
- u = tire road coefficient
- V = vertical force on the axle

Therefore,

$$H_f = u\ V_f \quad \text{and,} \quad H_r = U\ V_r \qquad (9a)$$

"Fishbone" Format, Ideal Balance Condition:

If we describe the braking forces as fraction rear braking, then the distribution producing ideal brake balance can be written as follows:

R_r = Fraction rear braking

$R_r = H_r/(H_f + H_r)$

Substituting for H_f and H_r from equation 9a,

$$R_r = u\ V_r/[u\ (V_f + V_r)] \qquad (10)$$

or

$$R_r = V_r/(V_f + V_r) \qquad (10a)$$

Using equation 4 and 10, the braking forces H_f and H_r can be expressed in terms of R_r as follows,

$$H_r = R_r\ (H_f + H_r) = R_r\ W\ A \qquad (10b)$$

and,

$$H_f = (1 - R_r)\ W\ A \qquad (10c)$$

at ideal braking, $R_r = R_4$,

Substituting for the values of V_f and V_r from equation 7 and 7a in to equation 10a, the following simplified equation for fraction rear braking at ideal balance is derived:

$$R_4 = (a - A\ h)\ /\ (a + b) \qquad (11)$$

The maximum attainable deceleration (A_{max}) without wheel lock up is equal to the tire-road coefficient of friction (u).

Equation 11 represents the fraction rear braking as a function of the deceleration at ideal brake balance. This equation corresponds to the "K = Z" equation for the ideal brake balance used in the adhesion utilization format. Using the vehicle parameters for the example vehicle described above yields the ideal brake balance line shown in Figure #2.

"Fishbone" Format based on Conditions other than Ideal Balance

In the absence of a perfect anti-lock brake system, a vehicle cannot be ideally balanced at all decelerations and loading conditions.

When the vehicle is rear biased, the rear axle reaches its limit of adhesion before the front axle, and the horizontal forces at the rear axle will equal the normal force at the rear axle multiplied by the tire-road coefficient. Thus, the rear axle limited deceleration , Ar is given by,

$$V_r \, u = R_r \, (A_r \, W) \tag{12}$$

Substituting for V_r from equation 7a,

$$u \, [W(a - A_r \, h)/(a + b)] = R_r \, A_r \, W$$

$$u \, (a - A_r \, h)/(a + b) = A_r \, R_r \tag{13}$$

Therefore,

$$A_r = u \, a \, / \, [(a + b)R_r + u \, h] \tag{14}$$

This rear axle limited deceleration vs. fraction rear braking is represented by the upper fishbone curves in Figure 3, one curve for each level of constant u from 0.1 to 1.0.

Likewise, for a front biased vehicle, the front axle reaches its limit of adhesion when the horizontal force at the front axle equals the normal force at front axle times the tire-road coefficient, i.e. the front axle limited deceleration is given by,

$$u\ V_f = (1 - R_r)\ A_f\ W$$

substituting for V_f from equation 6,

$$u\ (A_f\ W\ h + W\ b)/(a + b) = (1 - R_r)\ A_f\ W$$

This leads to,

$$A_f = u\ b\ /\ [(a + b)(1 - R_r) - u\ h] \qquad (15)$$

This front axle limited deceleration vs. fraction rear braking is represented by the lower fishbone curves in Figure 4, one curve for each level of u from 0.1 to 1.0.

Plotting of all curves given by equations 11, 14, and 15 on one chart gives the complete fishbone diagram for a given vehicle, thus providing the relationship between fraction rear braking (R_r) and deceleration (A) for various boundary conditions of tire-road coefficient of friction (u). The inputs required to generate this diagram are vehicle parameters W, h, wheel base (a + b); and the relationship between the static front and rear axle loads used to compute a and b.

Next, the braking forces at each axle for various values of deceleration are determined by either testing or by computation using the brake design parameters. This leads to the determination of fraction rear braking, which is plotted as a curve depicting brake balance for a given loading condition over the complete range of deceleration as illustrated in Figure 5 and

6 for the example vehicle. This method allows multiple brake component designs and brake balance configurations to be plotted on the same diagram, provided they are for the same vehicle design and loading condition. Further, this format allows prediction of the maximum deceleration attainable for any loading condition at any tire-road coefficient of friction.

Deviation From Ideal :

If we attempt to look at multiple loading conditions in the "fishbone" format, we find that the ideal line and the individual deceleration limit curves (ribs of the Fishbone) shift, resulting in an unusably complicated diagram as shown in Figure #6a.

In order to represent various loading conditions of the same vehicle on one diagram, we can instead use the offset or deviation from ideal brake balance for each condition (See figure 7). Here, the central horizontal axis is vehicle deceleration and the vertical axis is deviation of fraction rear braking (expressed in percentage) from ideal condition i.e.

$$\text{Deviation(f)} = R_f - R_4 \qquad (16)$$

$$\text{Deviation(r)} = R_r - R_4 \qquad (17)$$

Brake Efficiency at First Axle Lock:

A more refined comparison of a vehicle at various loading conditions, or vehicles with various static weight distributions can be made using the concept of brake efficiency at first axle lock.

Brake efficiency at first axle lock is defined as the ratio of deceleration at first axle lock divided by the theoretically attainable deceleration at ideal brake balance, i.e.

E = Brake Efficiency

$$E = 100\ (A\ /\ u) \tag{18}$$

Where,

A = Deceleration achieved at incipient wheelslide for the respective level of u.

If the vehicle is ideally balanced, the maximum deceleration attainable is equal to the tire-road coefficient of friction. Therefore, brake efficiency will be equal to 100%.

If the vehicle is rear biased, then the first axle to lock is the rear axle, and the brake efficiency is given by,

$$E_r = (A_r\ /\ u)\ 100$$

Substituting for A_r from equation 14,

$$E_r = 100\ a\ /[(a + b)\ R_r + u\ h\ ] \tag{19}$$

Similarly, if the vehicle is front biased, the ratio of front axle limited deceleration to the limiting deceleration is given by

$$E_f = (A_f\ /\ u)\ 100$$

substituting for A_f from equation 15,

$$E_f = 100\ b\ /\ [(a + b)(1 - R_r) - u\ h\ ] \tag{20}$$

The normalized brake efficiency plots at first axle lock for the example vehicle at unladen and laden conditions are shown in Figures 8 and 9. This format allows comparisons of various vehicles and various loading conditions on an equitable basis as shown in Figure 10 for the example vehicle at unladen and laden conditions. This format also allows a comparison of brake balance of various brake system designs for the same vehicle as shown in Figure 11 for variations of front axle brake outputs. Further, this format allows prediction of the maximum deceleration attainable for any loading condition at any tire to road coefficient of friction.

<u>Adhesion Utilization Format:</u>

A fourth and more common format for representing brake balance information is the adhesion utilization diagram. This is the format used in the ECE R13 Annex 10 and in the proposed FMVSS 135.

Adhesion Utilization is defined as the ratio of the horizontal braking force on an axle to the vertical force on that same axle, i.e.

$$F = H / V$$

where,

F is Adhesion Utilization and H and V are as previously defined.

In terms of fraction rear braking, the adhesion utilization for the front axle is given by substituting for H_f and V_f from equations 10c and 6 as follows,

$$F_f = [(1 - R_r) A W] / [W (b + A h) / (a + b)]$$

or,

$$F_f = (1 - R_r)\ A\ (a + b)\ /\ (b + A\ h) \qquad (21)$$

Similarly, for the rear axle, the adhesion utilization is given by substituting for H_r and V_r from equations 10b and 7a as follows,

$$F_r = R_r\ A\ W\ /\ [W\ (a - A\ h)\ /\ (a + b)]$$

or,

$$F_r = R_r\ A\ (a + b)\ /\ (a - A\ h) \qquad (22)$$

The normal adhesion utilization diagram plots F vs. A for the example vehicle at unladen and laden loading conditions are shown in Figure 12 and 13. This format includes a plot for each axle, front and rear. The corresponding brake efficiency curves are also shown at the top of Figures 12 and 13 for comparison purposes.

The ECE R13 and the proposed FMVSS 135 specify a maximum limit for front axle adhesion utilization which is represented by the equation,

$$K_f = (Z + .07)\ /\ .85 \qquad (23)$$

where,

K_f = adhesion utilization for front axle (corresponds to term F_f)

Z = deceleration (corresponds to term A)

Substituting for F_f from equation 21,

$(1 - R_r) A (a + b) / (b + A h) = (A + .07) / .85$

or,

$$R_r = 1 - [(A + .07)(b + A h)] / .85 A (a + b) \quad (24)$$

Similarly, an equation for any other condition or exception to the requirement can be derived in terms of rear brake fraction (R_r) and deceleration (A). For example, ECE R.13 allows inversion of the front and rear axle adhesion utilization curves in the range of deceleration values between 0.3 and 0.45 provided that the adhesion utilization value for rear axle does not exceed the line K = Z by more than 0.05. This condition can be expressed by the equation,

$$K_r = Z + .05 \quad (25)$$

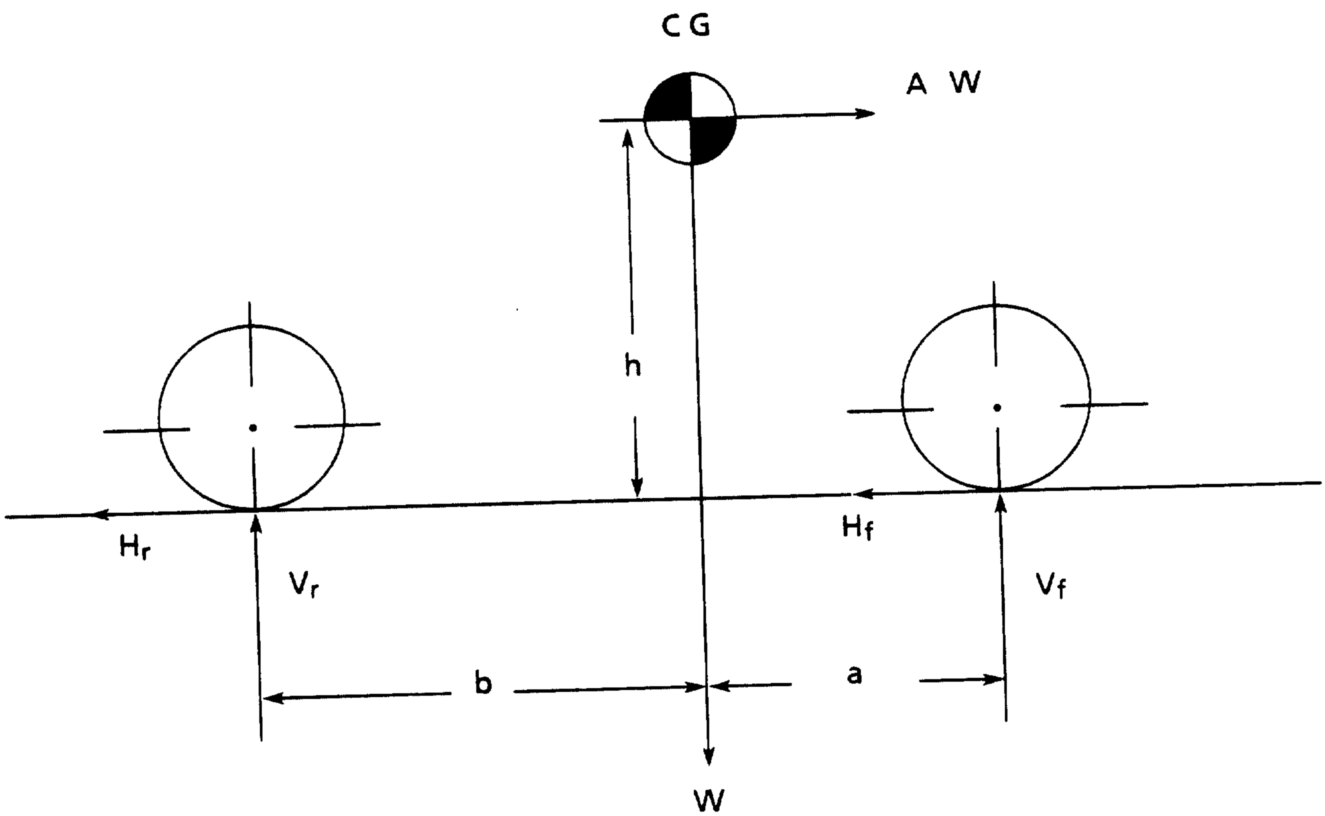
This condition also can be represented in terms of rear brake fraction, assuming rear adhesion utilization is at the limit of the allowable inversion window given by equation 25. Thus, substituting the value for F_r from equation 22 yields,

$F_r = A + .05 = R_r A (a + b) / (a - Ah)$

or,

$$R_r = (a - Ah)(A + .05) / A(a + b) \quad (26)$$

The adhesion utilization format makes it somewhat more difficult to plot more than two loading conditions, multiple design configurations, or a number of vehicles on the same plot. The adhesion utilization curves for the example vehicle for unladen and laden conditions are shown in Figure #14. Again, the efficiency curves are shown at the top for comparison purposes.


C G
A W
h
H_r
V_r
H_f
V_f
b
a
W

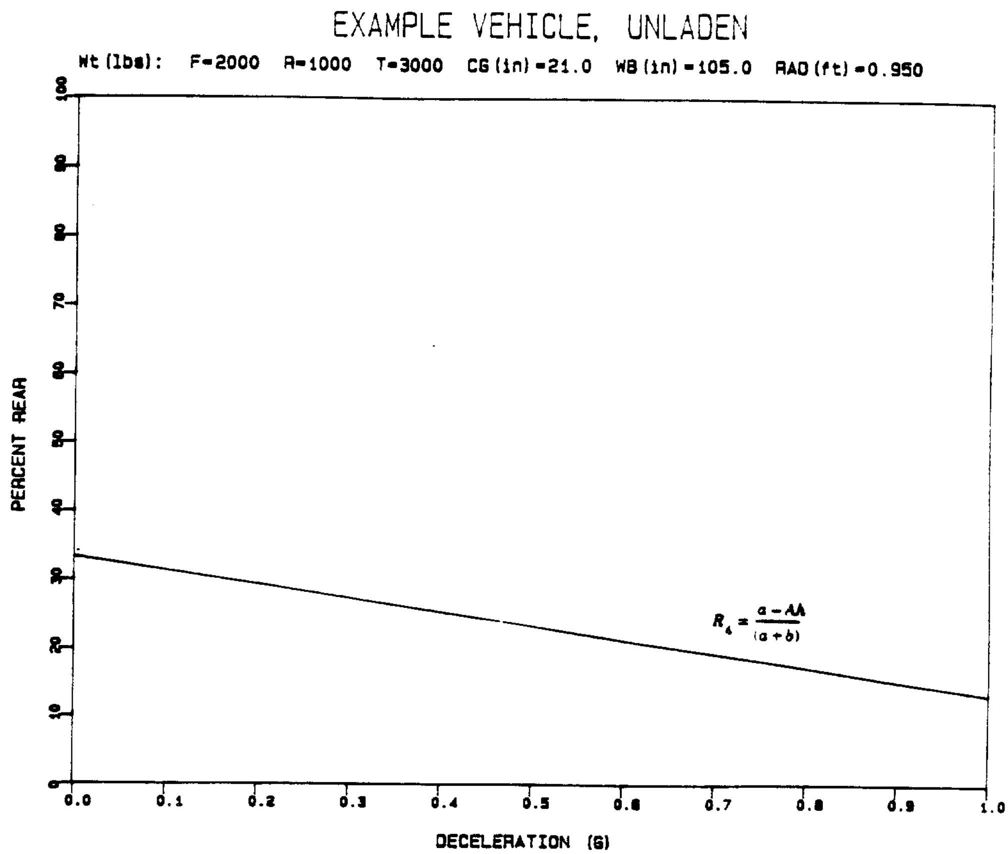


Figure 2

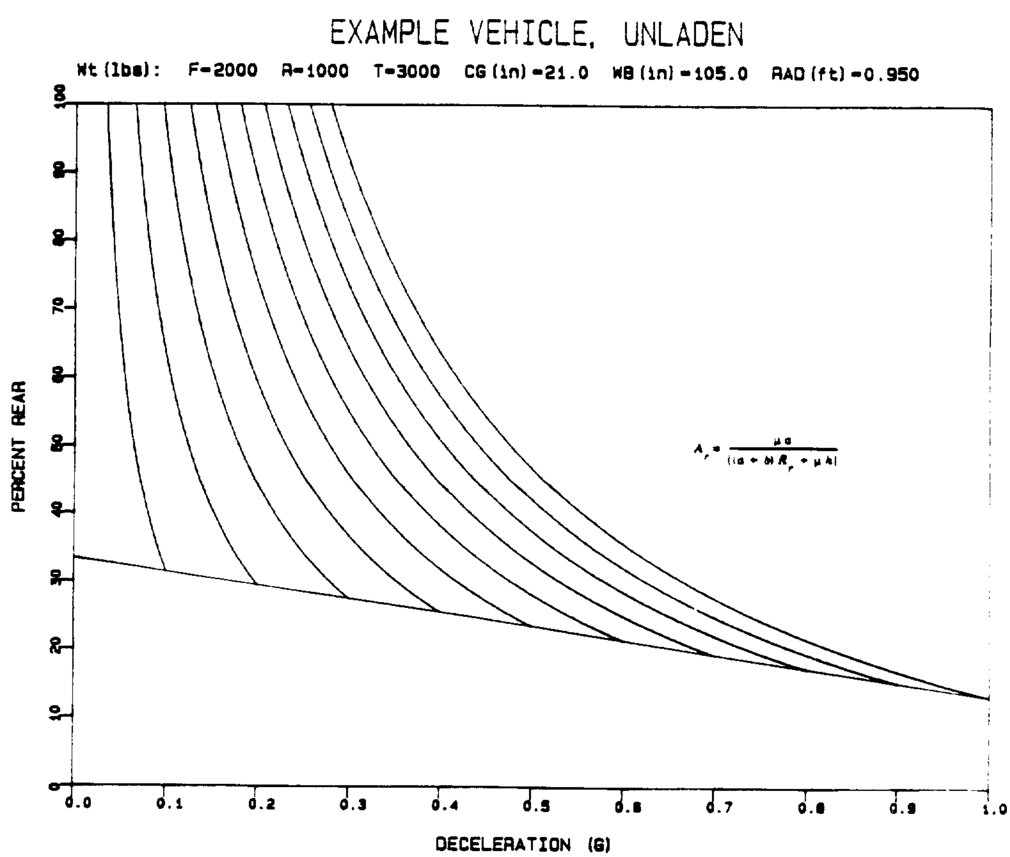


Figure 3

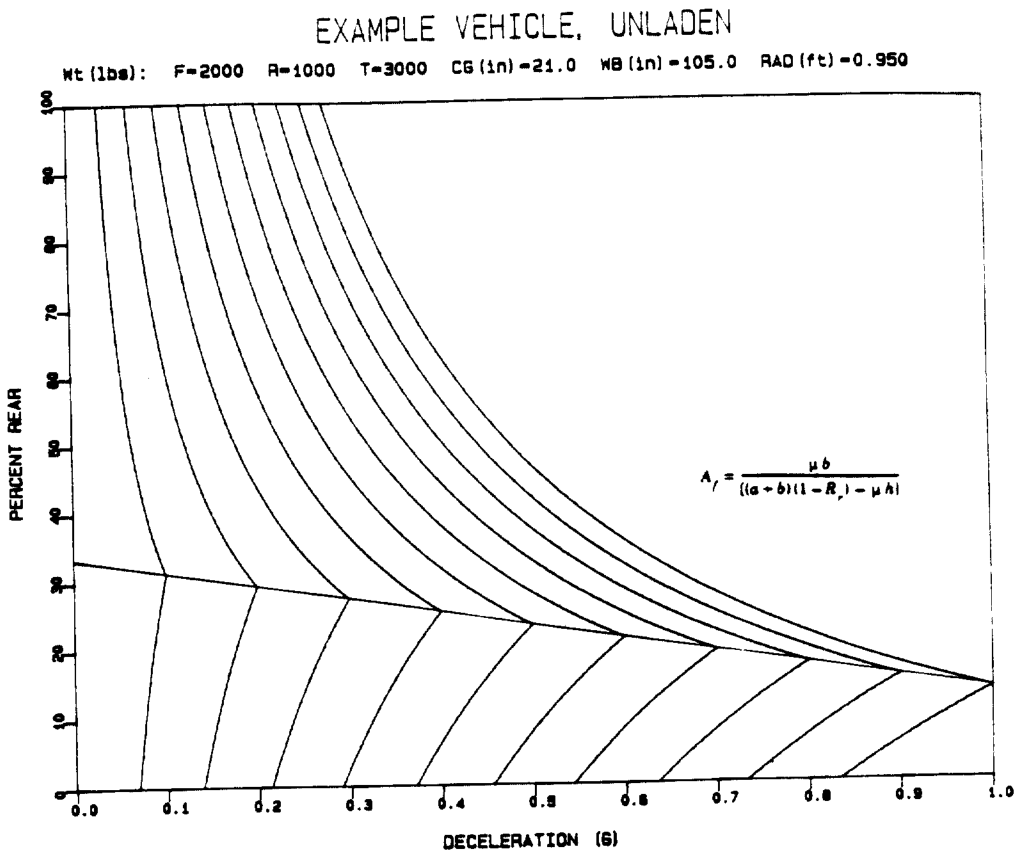


Figure 4

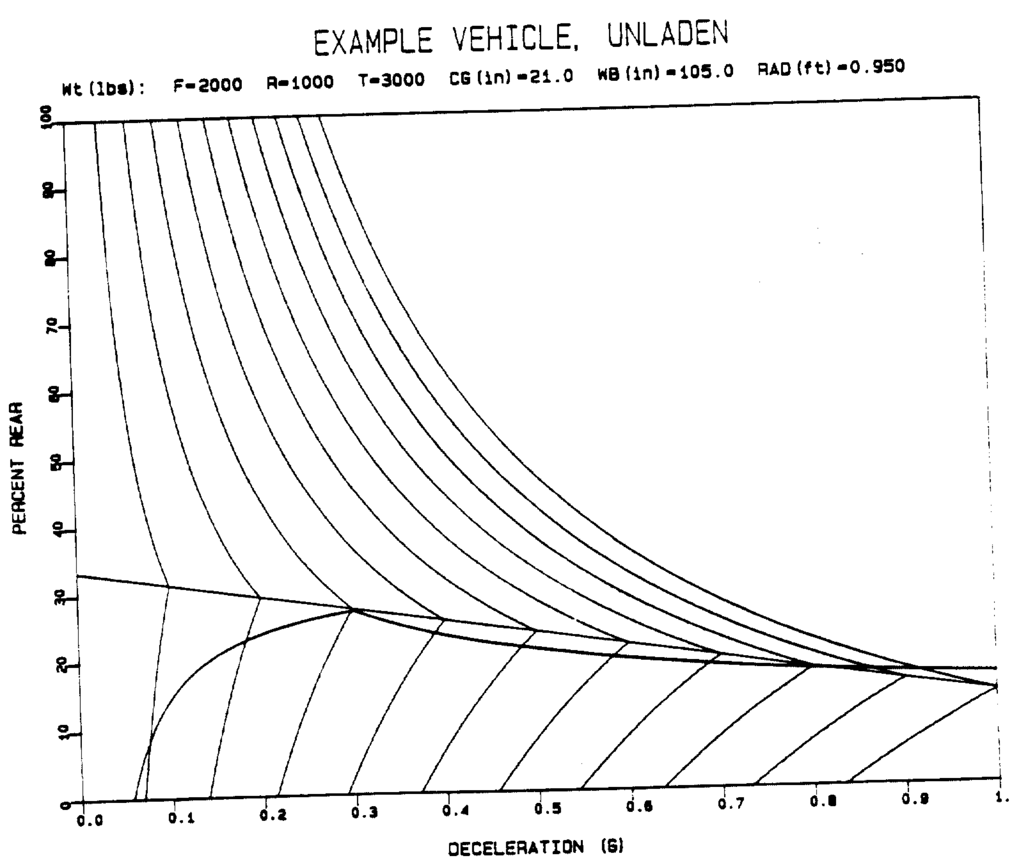


Figure 5

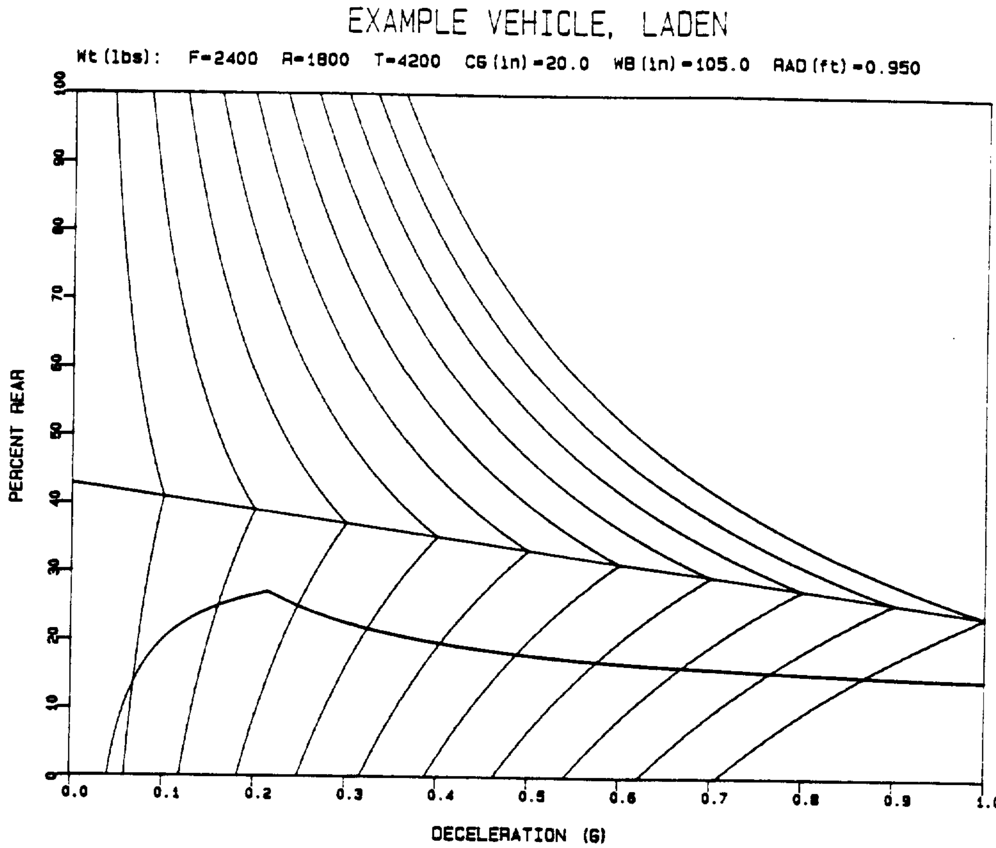


Figure 6

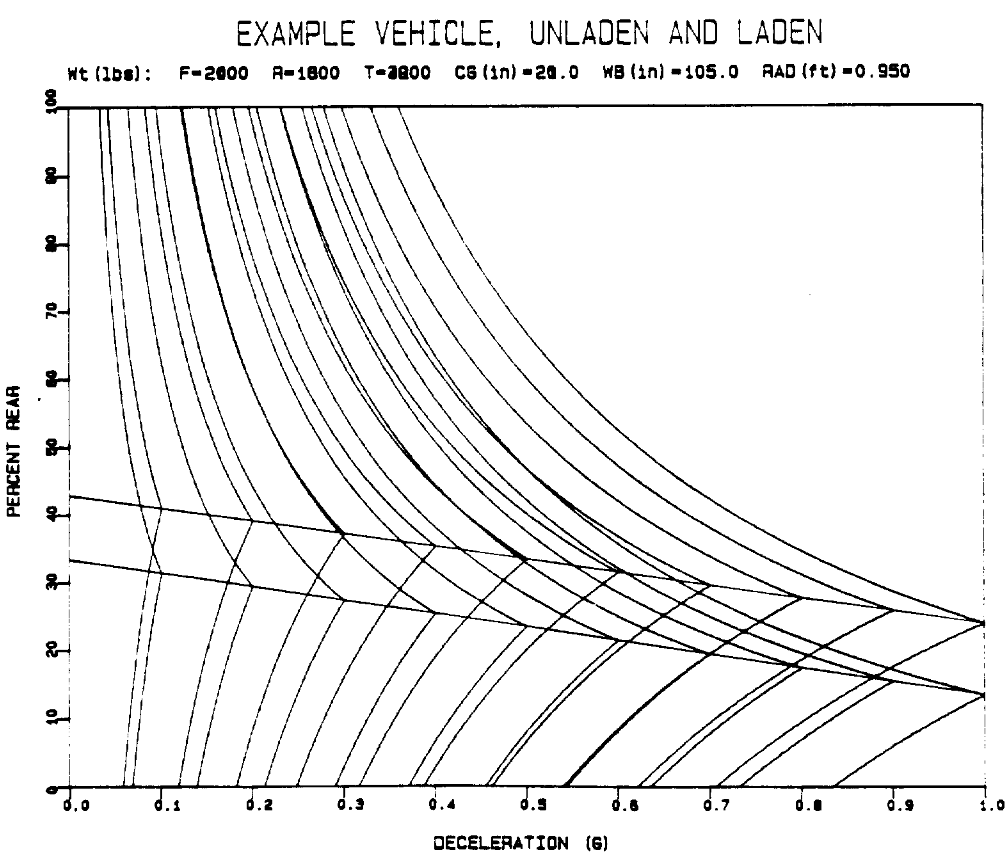


Figure 6A

EXAMPLE VEHICLE, LADEN AND UNLADEN

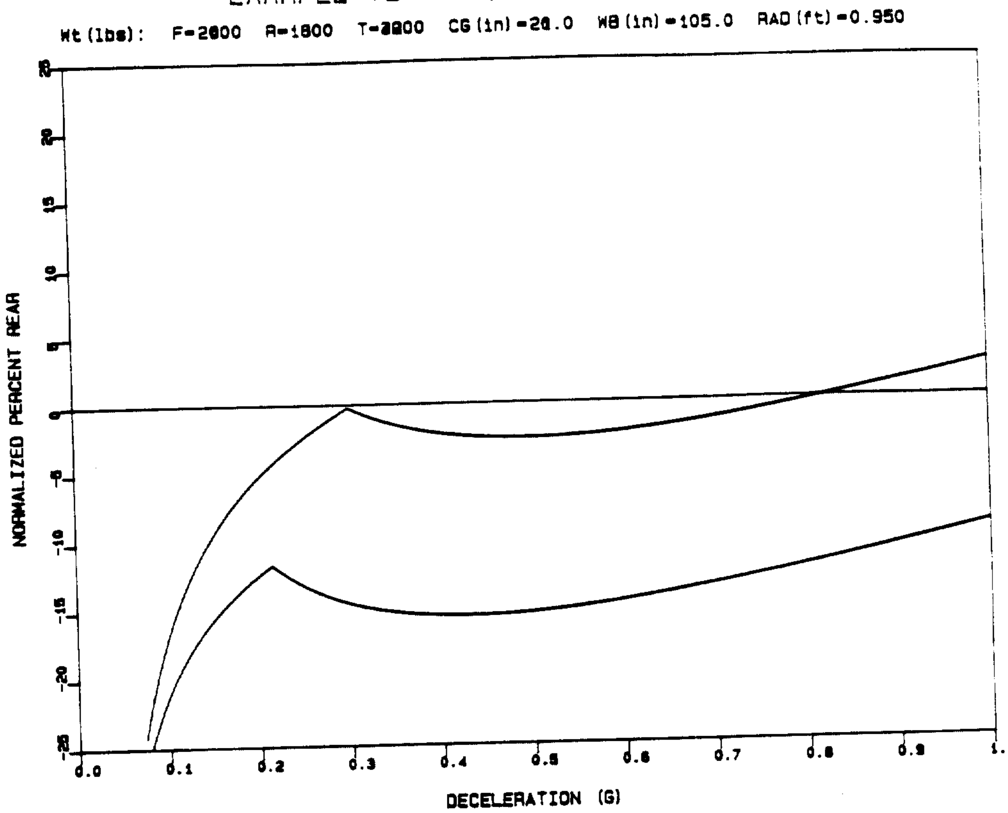


Figure 7

EXAMPLE VEHICLE, UNLADEN

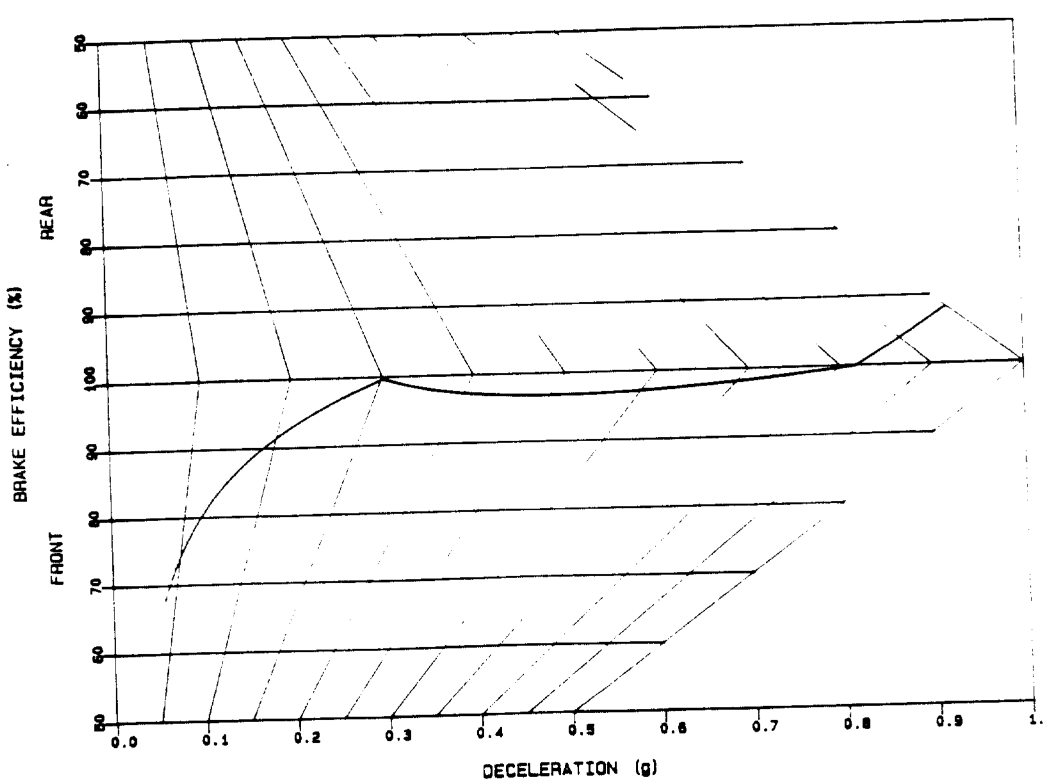


Figure 8

EXAMPLE VEHICLE, LADEN

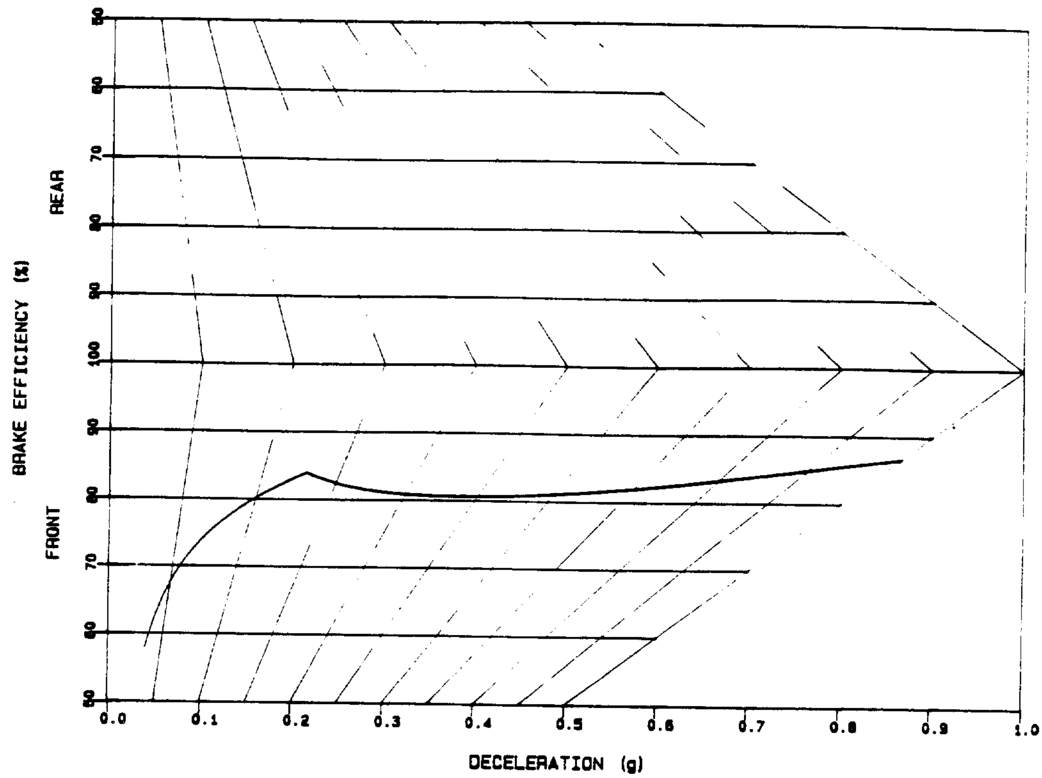


Figure 9

EXAMPLE VEHICLE, LADEN AND UNLADEN

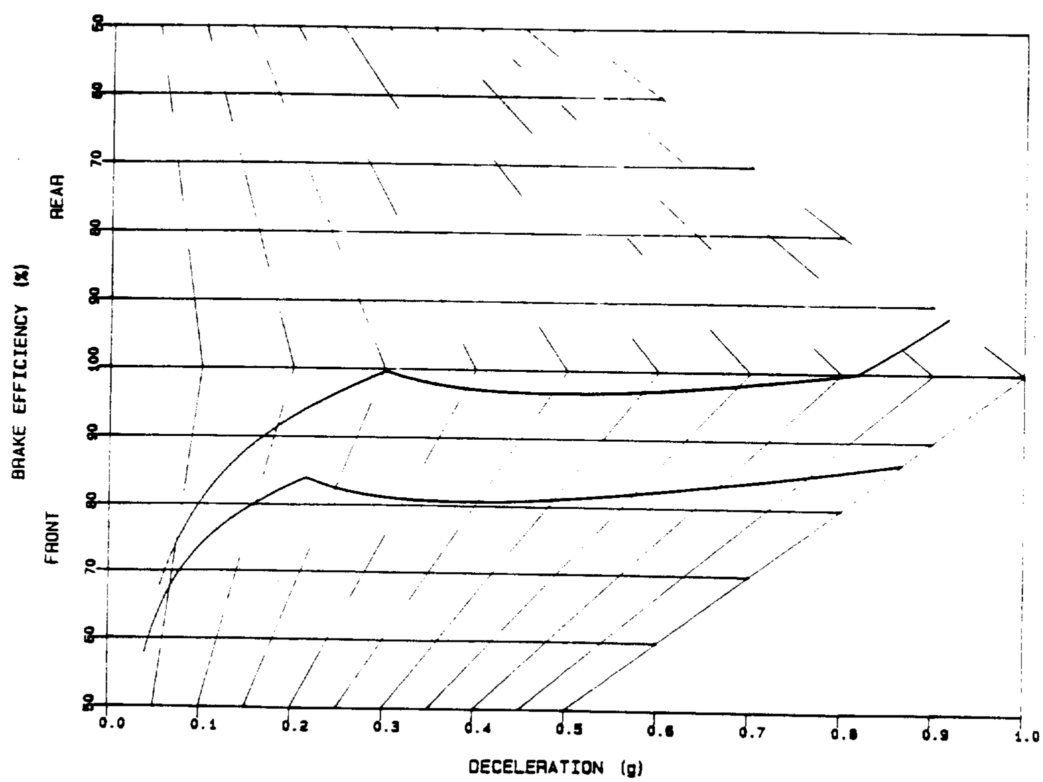


Figure 10

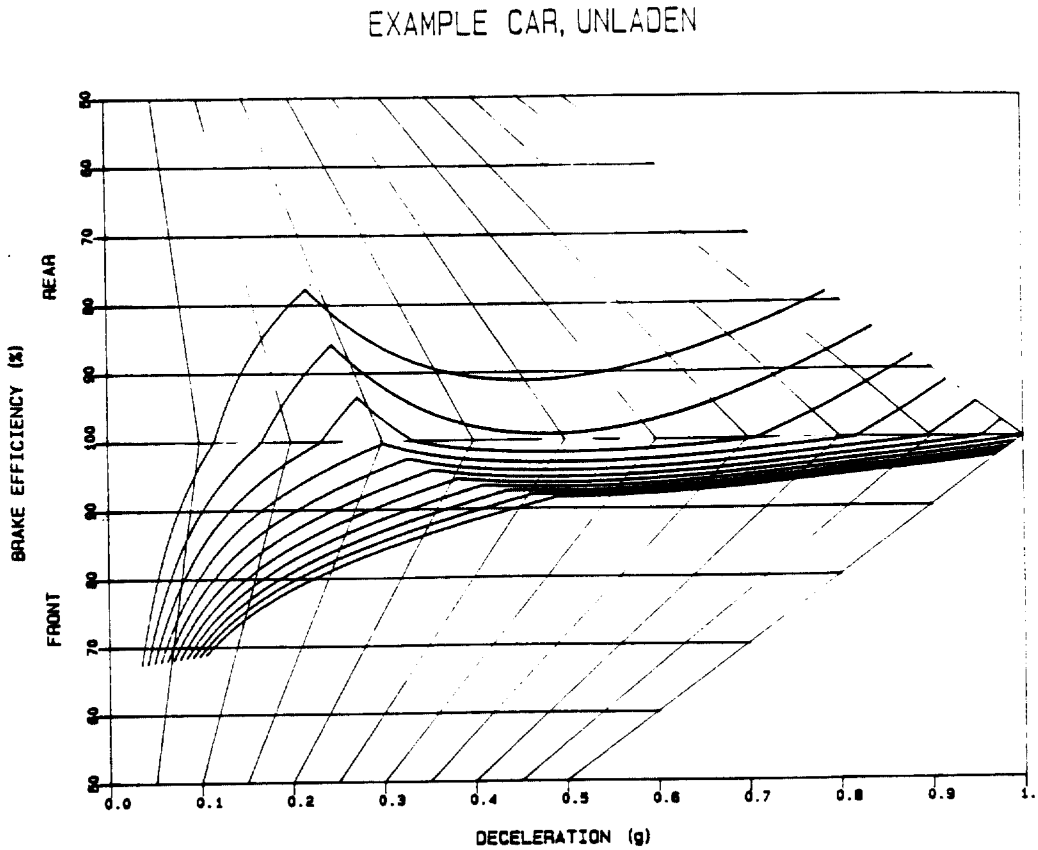


Figure 11

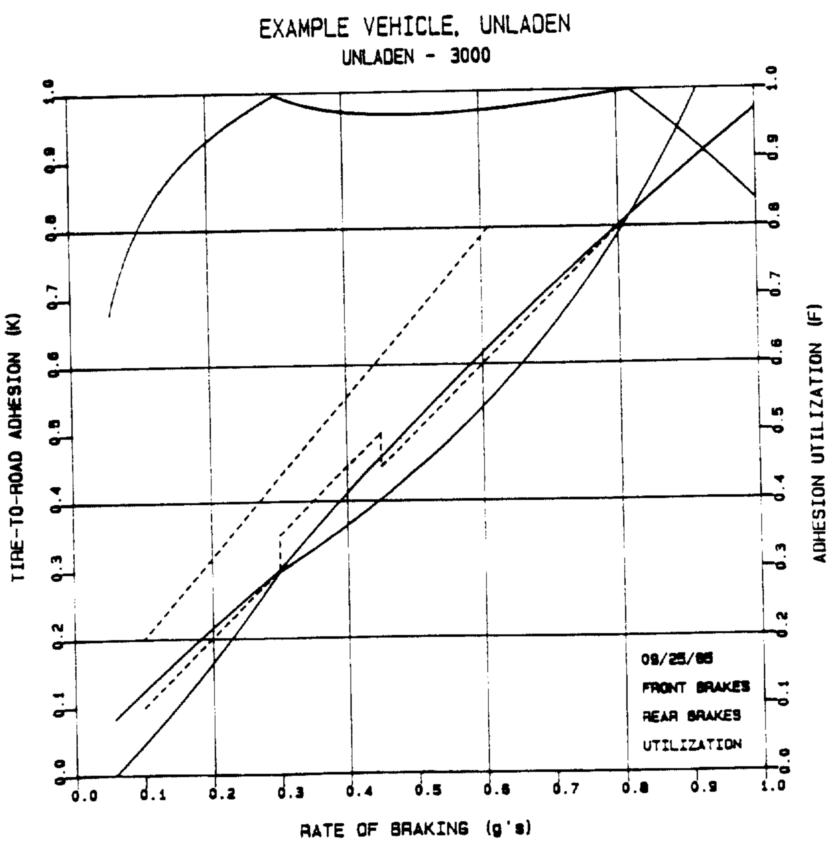


Figure 12

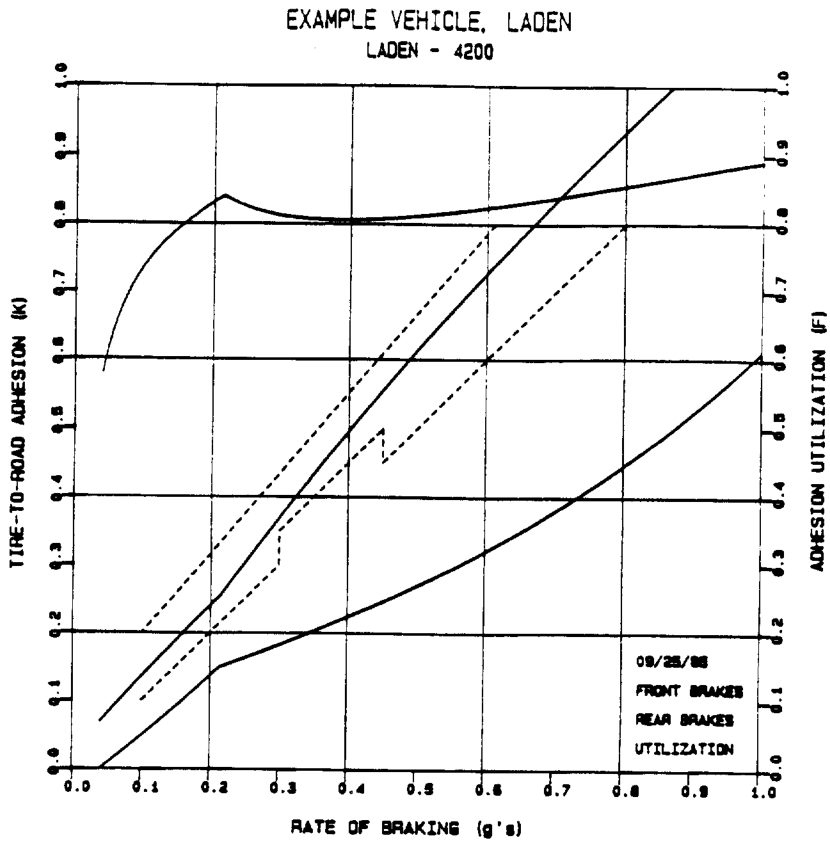


Figure 13

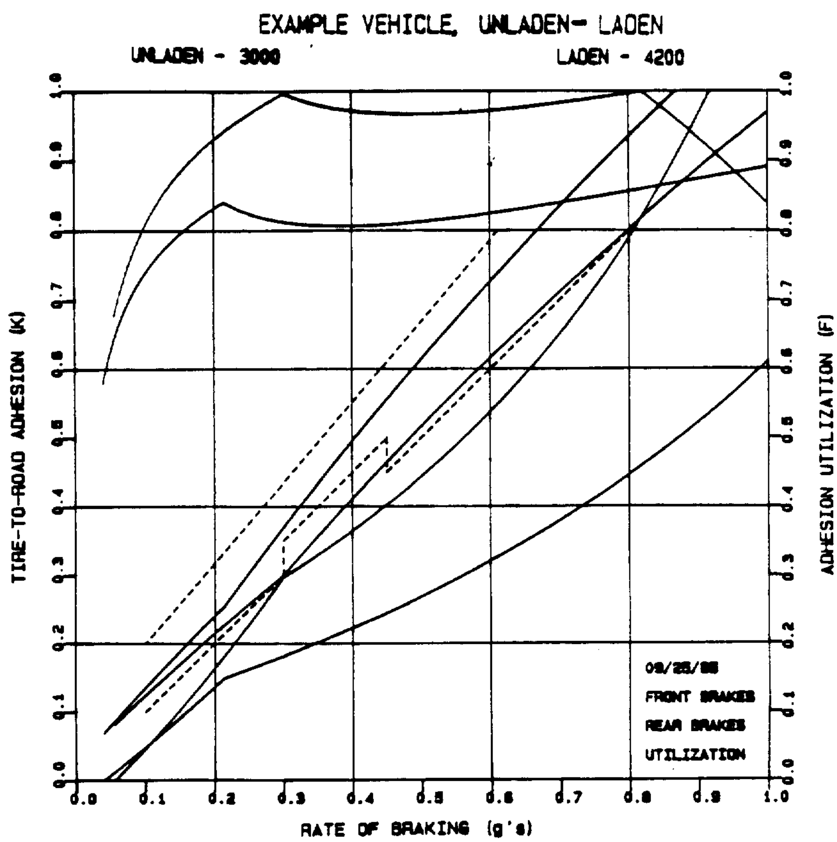


Figure 14

EXAMPLE VEHICLES

OBJECTIVE

This Appendix describes the two hypothetical vehicles which form the basis for all analytical discussions in this response regarding the limitations in brake system performance imposed by real world considerations, e.g. friction materials, tires, and the laws of physics. Two versions of each vehicle are described for the purpose of comparing the effects of a specific vehicle test for adhesion utilization.

DISCUSSION

The hypothetical vehicles, one front wheel drive (FWD) and one rear wheel drive (RWD), represent anticipated vehicle design configurations through the 1990's. Both example vehicles represent a typical 5 passenger automobile family that includes 1200 lbs (544.3 kg) of payload capacity to span the range of option contents, passengers and luggage. While the values selected for both FWD and RWD vehicles are not indicative of any particular motor vehicle on the market, they are an attempt to approximate a 90th percentile vehicle in terms of the issues of brake balance and stopping distances. In other words, brake performance achievable with these hypothetical vehicles would be achievable by at least 90% of the vehicle designs produced, in our estimation.

The specified front and rear weights, center of gravity height, tire size and wheel base, while not representing any particular vehicle, were chosen as typical values for both configurations. Brake systems are disc brakes with semi-metallic friction materials on the front axle and drum brakes with asbestos friction materials on the rear axle. The power assist is assumed to be provided through a vacuum booster. The hydraulic proportioning is assumed to be accomplished through a fixed knee and slope valve. While the brake system related parameters, e.g. front and rear specific torques, holdoff pressures, tire rolling radius, etc. are somewhat arbitrary, they are typical for vehicles intended for the North American market.

The brake balance for both example vehicles was "designed" in two basic configurations by varying front brake specific torque values. The first configuration, denoted without test (w/o test), is based on the assumption the NHTSA would accept adhesion utilization compliance by design calculation (or the assumed equivalent specific vehicle test with appropriate margins or tolerances) such that the nominal vehicle is controlled by the brake balance requirement. This configuration balances the brake system such that in the lightly loaded vehicle condition, the brake efficiency is very close to 100% over all decelerations, i.e. is very close to ideally balanced, as explained in Appendix 2, Derivation of Brake Balance Representations. The other configuration was based on the assumption that the NHTSA would require a specific vehicle test for adhesion utilization without allowance for variability, resulting in the extremes of the expected population variation being controlled by the brake balance requirement. In this case, the lightly loaded vehicle configuration is more front biased to provide for the anticipated range of brake balance variability. The only tabulated difference between the two configurations of each example are the values for front brake specific torque.

For comprehensive discussions on the issues that affect this aspect of brake sytem design the reader is referred to Appendix 4, Brake Balance Influence on Stopping Distance, and Appendix 12, Variability. Additionally, other factors related to the ratio of front to rear brake outputs are reviewed in detail in Appendix 19, Partial System Requirements.

The particular vehicle parameters selected for the FWD version of the example vehicle are given in table 1. Both versions of this vehicle, with and without a specific vehicle test for adhesion utilization are included. The resulting brake balance for both configurations is shown in Appendix 2, Derivation of Brake Balance Representations, but is repeated in this section as figures 1 and 2, for both the laden and unladen loading conditions.

The RWD example vehicle parameters are given in table 2. Again, both versions, with and without a specific vehicle test for adhesion utilization are included. The resulting brake balance for both the laden and unladen conditions of both vehicles are shown in figures 3 and 4.

TABLE 1. EXAMPLE FWD VEHICLE SPECIFICATIONS
ENGLISH

PARAMETER	W/O TEST		W/TEST	
	Unladen	Laden	Unladen	Laden
Front Weight, lbs	2000	2400	2000	2400
Rear Weight, lbs	1000	1800	1000	1800
CG Height, inches	21	20	21	20
CG to front axle, inches	35	45	35	45
CG to rear axle,inches	70	60	70	60
Wheelbase, inches	105	105	105	105
Tire Rolling Radius, ft	0.95	0.95	0.95	0.95
Front Brake Specific Torque,ft-lb/psi (Burnished)	0.80	0.80	1.50	1.50
Rear Brake Specific Torque,ft-lb/psi (Burnished)	0.40	0.40	0.40	0.40
Proportioning valve (psi x slope)	390 x 25%		390 x 25%	
Booster gain ratio	3.5 : 1		3.5 : 1	

Table 2. EXAMPLE RWD VEHICLE PARAMETERS
ENGLISH

PARAMETER	W/O TEST		W/TEST	
	Unladen	Laden	Unladen	Laden
Front Weight, lbs	1800	2280	1800	2280
Rear Weight, lbs	1200	1920	1200	1920
CG Height, inches	21	20	21	20
CG to front axle, inches	42	48	42	48
CG to rear axle, inches	63	57	63	57
Wheelbase, inches	105	105	105	105
Tire Rolling Radius, ft	0.95	0.95	0.95	0.95
Front Brake Specific Torque, ft-lb/psi (Burnished)	0.80	0.80	1.10	1.10
Rear Brake Specific Torque, ft-lb/psi (Burnished)	0.60	0.60	0.60	0.60
Proportioning Valve (psi x slope)	320 x 30%		320 x 30%	
Booster gain ratio	3.5 : 1		3.5 : 1	

TABLE 1. EXAMPLE FWD VEHICLE SPECIFICATIONS
METRIC

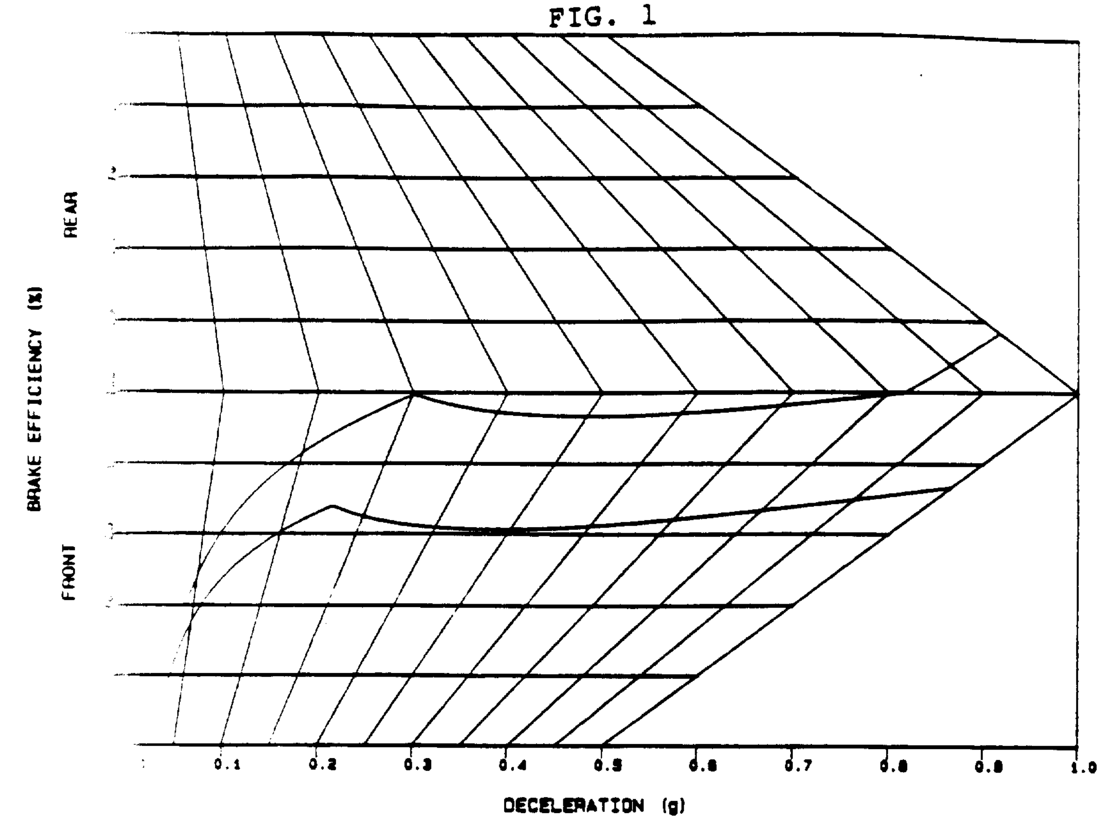
PARAMETER	W/O TEST		W/TEST	
	Unladen	Laden	Unladen	Laden
Front Weight, kg	907.2	1088.6	907.2	1088.6
Rear Weight, kg	453.6	816.5	453.6	816.5
CG Height, mm	533.4	508	533.4	508
CG to front axle, mm	889	1143	889	1143
CG to rear axle, mm	1778	1524	1778	1524
Wheelbase, mm	2667	2667	2667	2667
Tire Rolling Radius, m	0.29	0.29	0.29	0.29
Front Brake Specific Torque, Nm/kPa (Burnished)	0.157	0.157	0.295	0.295
Rear Brake Specific Torque, Nm/kPa (Burnished)	0.079	0.079	0.079	0.079
Proportioning valve (kPa x slope)	2689 x 25%		2689 x 25%	
Booster gain ratio	3.5 : 1		3.5 : 1	

Table 2. EXAMPLE RWD VEHICLE PARAMETERS
METRIC

PARAMETER	W/O TEST		W/TEST	
	Unladen	Laden	Unladen	Laden
Front Weight, kg	816.5	1034.2	816.5	1034.2
Rear Weight, kg	544.3	870.9	544.3	870.9
CG Height, mm	533.4	508	533.4	508
CG to front axle, mm	1066.8	1219.2	1066.8	1219.2
CG to rear axle, mm	1600.2	1447.8	1600.2	1447.8
Wheelbase, mm	2667	2667	2667	2667
Tire Rolling Radius, m	0.29	0.29	0.29	0.29
Front Brake Specific Torque, Nm/kPa (Burnished)	0.157	0.157	0.216	0.216
Rear Brake Specific Torque, Nm/kPa (Burnished)	0.118	0.118	0.118	0.118
Proportioning Valve (kpa x slope)	2206 x 30%		2206 x 30%	
Booster gain ratio	3.5 : 1		3.5 : 1	

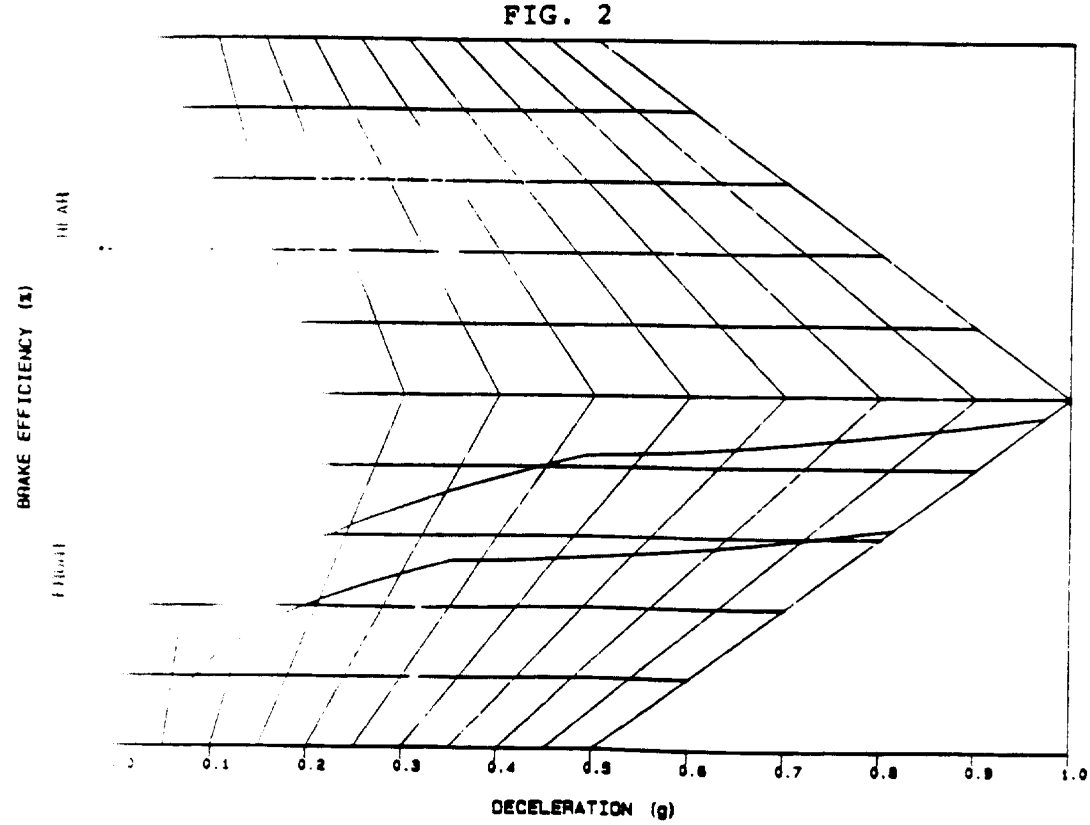
EX FWD VECH W/O TEST, LADEN AND UNLADEN

FIG. 1



EX FWD VECH W/TEST, LADEN AND UNLADEN

FIG. 2



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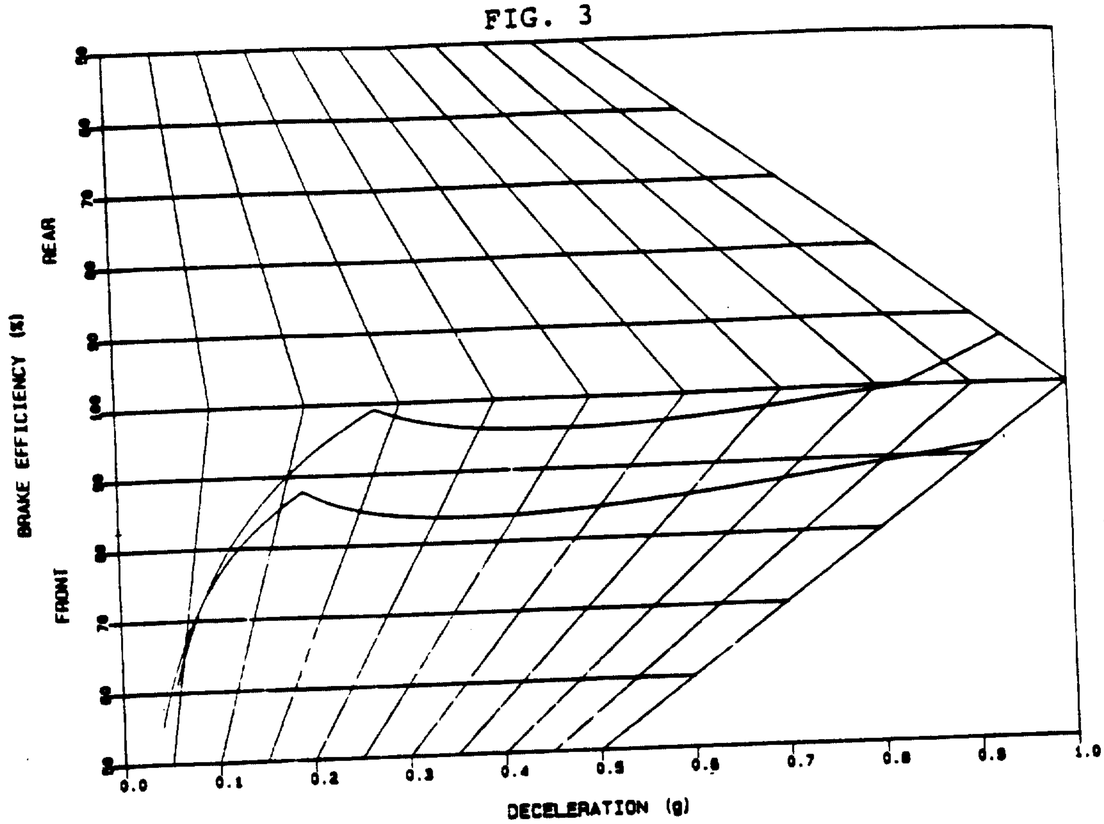
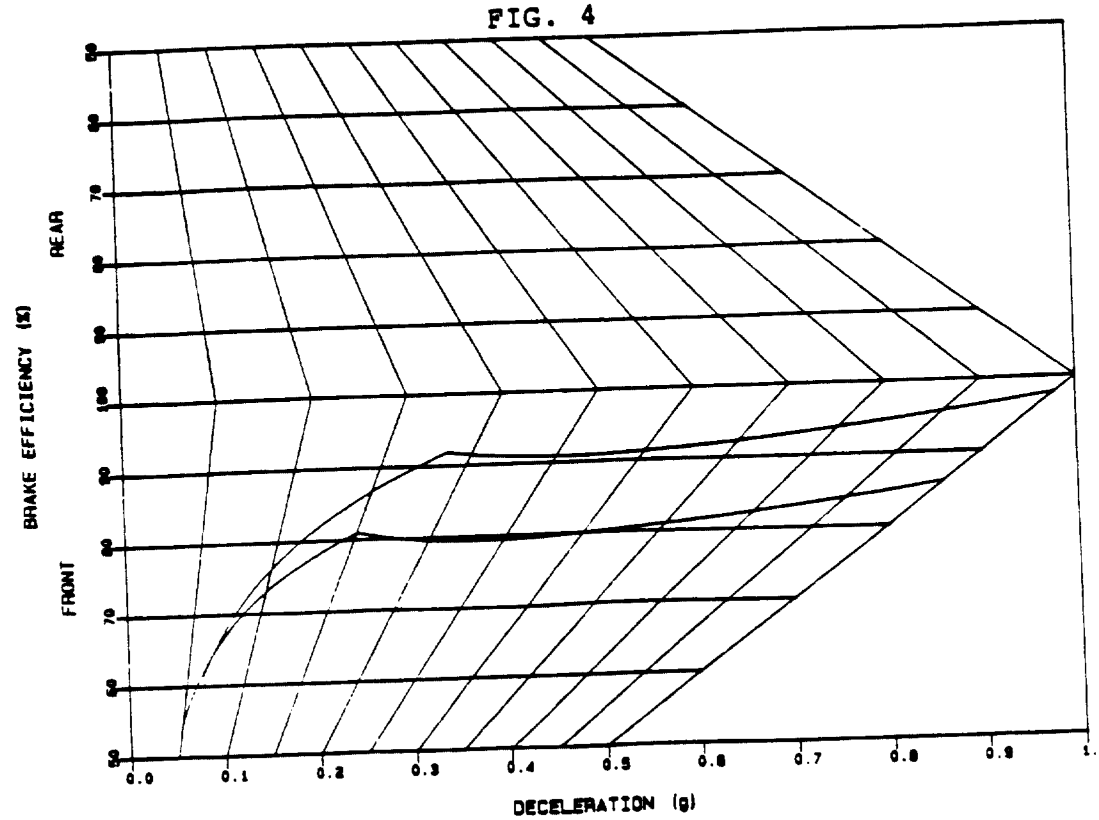
EX AWD VECH W/O TEST, LADEN AND UNLADEN

FIG. 3



EX AWD VECH W/TEST, LADEN AND UNLADEN

FIG. 4



BRAKE BALANCE INFLUENCE ON STOPPING DISTANCE

OBJECTIVE

This section examines the effect of brake balance on stopping distance. This discussion also quantifies the effect of prescribing the use of a vehicle test for balance certification vs using a calculation or nominal approach, as is used in ECE R13.

CONCLUSIONS

1. Imposition of a brake balance requirement which does not allow rear bias necessarily results in longer stopping distances than one that does allow rear bias. Specifically, for our FWD example vehicle, a front biased brake balance requirement adds distance to each GVWR stop.

2. Brake balance necessary to prevent rear bias in all vehicles considering the variability distribution (i.e. incorporating a vehicle test for compliance) necessarily results in longer stopping distances than that necessary to design the nominal vehicle to prevent rear bias (using a calculation for balance determination).

RECOMMENDATIONS

1. NHTSA should adopt the same approach to brake balance regulation as used in Europe, that is a calculation that describes the nominal vehicle design. NHTSA should avoid a brake balance regulation that forces the stopping distances to be lengthened unnecessarily by prescribing that the extremes of the vehicle population variability all meet the specified balance, as would a vehicle test.

DISCUSSION

This response section demonstrates the effect of requiring front axle limited brake balance design on the stopping distance capability of a vehicle, as compared with that likely under the influence of only FMVSS 105. This section goes on to determine the effect of requiring the use of a physical test to verify front axle limited brake balance on the stopping distance capability.

To make these comparisons, consider the example vehicles introduced in Appendix 3, Example Vehicles. To build these vehicles with the greatest margin of compliance with FMVSS 105, the brake designer would balance the front and rear brake outputs in such a way that the vehicle would be rear axle limited in the lightly loaded condition, and front axle limited in the laden condition. This brake balance leads to the shortest combination of stopping distances for the spread of test conditions specified in FMVSS 105. This shortest stopping distance (SSD) balance will be calculated below.

To simplify the calculations, we can assume that green to burnished transitions in friction materials and tires do not exist, and that front and rear foundation brake output does not change throughout the test sequence of FMVSS 105. Further, we will assume a peak tire to road coefficient of 0.80 for all test conditions. Finally, we will assume a 0.60 second reaction time. These assumptions result from analyses in Appendix 9, Brake System Reaction Time, and Appendix 7, Tire Design Considerations.

To obtain the shortest stopping distances throughout the loading range from unladen to laden, both example vehicle configurations can be balanced such that the rear axle limited deceleration in the unladen condition is exactly equal to the front axle limited deceleration in the laden condition. The fraction rear brake that meets this criterion is given by equating the deceleration limits of front and rear axles in the laden and unladen conditions respectively and solving for "R_r". Thus, from equations 14 and 15 of Appendix 2:

$$ua/[(a+b)R_r+uh] = ub/[(a+b)(1-R_r)-uh] \qquad (1)$$

where the left hand side of (1) is the rear axle limited deceleration in the unladen condition and the right hand side of (1) is the front axle limited deceleration in the laden condition.

Front Wheel Drive Example Vehicle

For the FWD example vehicle, using the values described in Appendix 3, equation (1) becomes

$$(0.80)(35)/(105R_r+(0.80)(21)) = (0.80)(60)/((105(1-R_r))-(0.80)(20)) \qquad (2)$$

which yields a value for R_r, the rear brake fraction, of 0.213. This value can be substituted back into either side of (1) to yield a deceleration rate of 0.72g (23.2 ft/s^2, 7.1 m/s^2). This value represents both the front axle limited deceleration rate in the laden condition and the rear axle limited deceleration rate in the unladen condition, for the particular vehicle and tire to road coefficient assumed. Since we are assuming for purposes of this calculation that no changes in output occur due to burnish, we are free to calculate the total stopping distance of the first, second, third and fourth effectiveness portions of FMVSS 105. These are given in Table 1 under the column labeled "FWD SSD".

For comparison, stopping distances were calculated for both the version of the FWD example vehicle balanced for a standard that prescribes the calculation methodology for adhesion utilization and the version of the same vehicle that is balanced comprehending the use of a physical test. These stopping distances are compared in Table 1 with the short stopping distance (SSD) version whose rear brake fraction is given by equation (2) above. These calculations were made for all of the full system effectiveness tests in FMVSS 105. Note that for this example vehicle, all GVWR stopping distances increase and the LLVW stopping distance decreases.

The direct effect of requiring front bias and adding a specific vehicle test for it can be seen for each test by comparing values given in Table 1 for each test condition. However, FMVSS 105 requires a vehicle to meet a series of full system effectiveness tests, most of which are at GVWR. Thus additional insight into the effect of the balance requirements combined with the heavy emphasis on GVWR testing can be gained by adding the effect thereof on all the full system effectiveness tests. From Table 1 we can see that the <u>total</u> FMVSS 105 effectiveness test stopping distance is 64.4 m (211.4 feet) shorter for the FWD example vehicle SSD configuration (rear biased lightly loaded and front biased at GVW) than for the front axle limited version without a specific vehicle test for adhesion utilization, and 111.5 m (365.7 feet) shorter than the version consistent with a test for adhesion utilization. For this FWD example vehicle, the inclusion of a specific vehicle test for adhesion utilization adds a total of 47 m (154.3 feet) to the stopping distances.

Rear Wheel Drive Example Vehicle

Similar calculations (using the same assumptions) have been made for the example RWD vehicle, using the relationship given in (1). This calculation yields a shortest stopping distance (rear axle limited in the lightly loaded vehicle condition) deceleration of 0.75g (24.2 ft/s^2, 7.4 m/s^2). The total FMVSS 105 stopping distances are shown in table 2.

For the example RWD vehicle, the requirement of front axle limited brake balance certified by calculation adds 32.6 m (107.4 feet) net to the total FMVSS 105 stopping distance. With a specific vehicle test for brake balance the total FMVSS 105 stopping distance is 67.2 m (220.5 feet) longer than the shortest stopping distance (SSD) configuration, which is rear biased lightly loaded. The stopping distance penalty for adding the specific vehicle test for adhesion utilization is 34.5 m (113.1 feet).

This exercise has illustrated that indeed there is a trade off between brake balance and stopping distance. In fact, the addition of a front axle limited brake balance requirement (based on calculation) adds a net 64.4 m (211.4 feet) to the total of the FMVSS 105 stopping distances in full system effectiveness tests for the FWD example vehicle. Simply adding a specific vehicle test for brake balance, rather than adopting the European calculation approach, adds up to an additional 47 m (154 feet) to the total stopping distances.

TABLE 1. EXAMPLE FWD VEHICLE

CALCULATED MINIMUM STOPPING DISTANCES IN FMVSS 105

TEST PORTION	LOADING	SPEED	FWD SSD	FWD W/O TEST	FWD W/TEST
		mph	feet	feet	feet
First Eff	GVW	30	54.9	58.1	61.7
	GVW	60	193.5	206.0	220.5
Second Eff	GVW	30	54.9	58.1	61.7
	GVW	60	193.5	206.0	220.5
	GVW	80	332.3	354.5	380.3
Third Eff	LLV	60	193.5	178.7	186.9
Fourth Eff	GVW	30	54.9	58.1	61.7
	GVW	60	193.5	206.0	220.5
	GVW	80	332.3	354.5	380.3
	GVW	100	508.5	543.2	583.4
TOTAL			2011.8	2223.2	2377.5
Difference			211.4	154.3	

SSD = Shortest Stopping Distance - Based on vehicle being rear biased @ LLVW and front Biased @ GVWR.

W/O TEST = Without Test - Based on certifying front bias by calculation using nominal vehicle parameters.

W/TEST = With Test - Based on certifying front bias by vehicle test which would be applicable to every vehicle.

TABLE 2. EXAMPLE RWD VEHICLE

CALCULATED MINIMUM STOPPING DISTANCES IN FMVSS 105

TEST PORTION	LOADING	SPEED	RWD SSD	RWD W/O TEST	RWD W/TEST
		mph	feet	feet	feet
First Eff	GVW	30	53.3	56.2	58.8
	GVW	60	186.9	198.3	208.7
Second Eff	GVW	30	53.3	56.2	58.8
	GVW	60	186.9	198.3	208.7
	GVW	80	320.4	340.8	359.3
Third Eff	LLV	60	186.9	178.7	186.9
Fourth Eff	GVW	30	53.3	56.2	58.8
	GVW	60	186.9	198.3	208.7
	GVW	80	320.4	340.8	359.3
	GVW	100	489.9	521.8	550.7
Total			2038.2	2145.6	2258.7

Difference	107.4	113.1

SSD = Shortest Stopping Distance - Based on vehicle being rear biased @ LLVW and front Biased @ GVWR.

W/O TEST = Without Test - Based on certifying front bias by calculation using nominal vehicle parameters.

W/TEST = With Test - Based on certifying front bias by vehicle test which would be applicable to every vehicle.

TABLE 1 METRIC. EXAMPLE FWD VEHICLE

CALCULATED MINIMUM STOPPING DISTANCE IN FMVSS 105

TEST PORTION	LOADING	SPEED	FWD SSD	FWD W/O TEST	FWD W/TEST
		km/h	meters	meters	meters
First Eff	GVW	48.3	16.7	17.7	18.8
	GVW	96.6	59	62.8	67.2
Second Eff	GVW	48.3	16.7	17.7	18.8
	GVW	96.6	59	62.8	67.2
	GVW	127.7	101.3	108.1	115.9
Third Eff	LLV	96.6	59	54.5	57
Fourth Eff	GVW	48.3	16.7	17.7	18.8
	GVW	96.6	59	62.8	67.2
	GVW	127.7	101.3	108.1	115.9
	GVW	160.9	155	165.6	177.8
TOTAL			613.2	677.6	724.7
Difference				64.4	47

SSD = Shortest Stopping Distance - Based on vehicle being rear biased @ LLVW and front Biased @ GVWR.

W/O TEST = Without Test - Based on certifying front bias by calculation using nominal vehicle parameters.

W/TEST = With Test - Based on certifying front bias by vehicle test which would be applicable to every vehicle.

TABLE 2 METRIC. EXAMPLE RWD VEHICLE

CALCULATED MINIMUM STOPPING DISTANCES IN FMVSS 105

TEST PORTION	LOADING	SPEED	RWD SSD	RWD W/O TEST	RWD W/TEST
		km/h	meters	meters	meters
First Eff	GVW	48.3	16.2	17.1	17.9
	GVW	96.6	57	60.4	63.6
Second Eff	GVW	48.3	16.2	17.1	17.9
	GVW	96.6	57	60.4	63.6
	GVW	127.7	97.7	103.9	109.5
Third Eff	LLV	96.6	57	54.5	57
Fourth Eff	GVW	48.3	16.2	17.1	17.9
	GVW	96.6	57	60.4	63.6
	GVW	127.7	97.7	103.9	109.5
	GVW	160.9	149.3	159	167.9
Total			621.4	654	688.5
Difference				32.6	34.5

SSD = Shortest Stopping Distance - Based on vehicle being rear biased @ LLVW and front Biased @ GVWR.

W/O TEST = Without Test - Based on certifying front bias by calculation using nominal vehicle parameters.

W/TEST = With Test - Based on certifying front bias by vehicle test which would be applicable to every vehicle.

THE BRAKE BALANCE "WINDOW" IN FMVSS 135

OBJECTIVE

The purpose of this Appendix is to identify the concept of a "window" of allowable brake balance that is created by the requirements that a vehicle be front axle limited in all loading conditions, and the stopping distance in the laden or GVW loading condition. This "window" becomes the target within which the brake designer must balance the vehicle. Further this response section calculates and compares the magnitude of the "window" in FMVSS 135, FMVSS 105, ECE R13, and ECE R88.

CONCLUSIONS

1. The "window" of permissible vehicle brake balance in FMVSS 135 is 3.29 percentage points in fraction rear braking, for the example FWD vehicle.

2. The "window" of brake balance in FMVSS 105 is 10.64 percentage points. ECE R13 and R88 both provide a "window" of 17.33 percentage points, for the example FWD vehicle.

3. The proposed FMVSS 135 does not allow sufficient brake balance "window" to allow certification of both stopping distance compliance and front bias compliance.

4. Preserving the "window" in FMVSS 105, and adopting the front bias emphasis of FMVSS 135 with certification by nominal design calculation, results in full system effectiveness stopping distance of 249.8 feet for equivalency with FMVSS 105. When a correction for the reduced number of attempts is made, a requirement equivalent to FMVSS 105 would be 253 feet.

RECOMMENDATIONS

1. The final harmonized rule should have stopping distances longer than provided in FMVSS 135. A full system effectiveness requirement of 252.6 feet preserves the "window" of FMVSS 105, and is precisely the value proposed in ECE R88.

2. The certification of vehicle brake balance should be accomplished using the calculation method, not using a physical test as currently employed in ECE R13.

DISCUSSION

The subject of vehicle brake balance and its relationship to stopping distance is a concern to both the manufacturer and the regulatory community. Since both peak traction and brake balance limit deceleration rate, the stopping distance requirements of a harmonized brake regulation must be consistent with any regulation of brake balance.

The brake balance that is required to yield a vehicle design which complies with FMVSS 135 is limited by two conditions. These create a "window" within which the brake balance must lie in order to satisfy the regulation. These two conditions are 1) the stopping distance requirements in the GVW loading condition and 2) the requirement that the vehicle be front biased in all loading conditions.

The stopping distance requirements specified in the proposed FMVSS 135 are inconsistent with the brake balance requirements contained within the same proposal. The deceleration limits which vehicles are able to achieve on production tires are described in Appendix 16 (Pre-Burnished Brake Effectiveness) and

Appendix 17 (Burnished Brake Performance), where theoretical minimum stopping distances are calculated.

To understand the concept of a "window" one must consider first the requirement that all vehicles be front biased. The fishbone diagram, where "percent rear braking" is plotted against "deceleration rate", includes a line representing the ideal balance, with regions above that line indicating rear brake lockup before front (see Appendix 2, Derivation of Brake Balance Representation). The requirement that a vehicle be designed to be front axle limited under all loading conditions, up to a deceleration of 0.80g, establishes a maximum amount of rear braking that will be allowed. This maximum allowable fraction rear braking is given by the ideal rear brake fraction at 0.80g deceleration, i.e.,

$$R_4 = (a-Ah)/(a+b) \qquad \text{(equation 11, Appendix 2)}$$

where,

R_4 = fraction rear braking at four wheel lock-up (ideal brake balance)

a = horizontal distance between the C.G. and front axle

b = horizontal distance between the C.G. and rear axle

A = vehicle deceleration, in terms of g

h = C.G. height above roadway

(a+b) = vehicle wheelbase

For the FWD example vehicle (described in Appendix 3, Example Vehicles), at 0.80g, the maximum fraction rear braking allowed, established in the unladen (LLV) vehicle loading condition, is given by

$$R_4 = [35 - (0.80)(21)] / 105$$

$$R_4 = 0.1733$$

The other limiting condition results from the stopping distance requirements at GVW. The minimum rear brake fraction is determined by the vehicle deceleration rate necessary to meet the GVW stopping distance specified. For the requirement of FMVSS 135, this minimum is established by the cold effectiveness requirement for the laden vehicle. The front axle limited deceleration rate is given by,

$A_f = u\ b / \{[(a+b)(1-R_r)] - u\ h\}$ (equation 15, Appendix 2)

which is equivalent to,

$$R_r\ (min) = 1 - u[(b + A_f\ h) / A_f(a+b)]$$

where,

R_r (min) = minimum fraction rear braking

u = tire-road peak coefficient of friction

Af = front axle limited vehicle deceleration

For the same FWD example vehicle, without a physical test for brake balance, the minimum fraction rear braking can be calculated from the FMVSS 135 specified stopping distance requirement of 214 feet in the laden condition. Using the 0.60 second brake system reaction time (see Appendix 9, Brake System Reaction Time), this stopping distance is equivalent to a minimum average vehicle deceleration of 0.70g. In order to achieve this deceleration at u=0.8, the example FWD vehicle must have a minimum rear brake fraction of 0.0904, i.e., R_r (min) = 0.0904.

Thus, for these assumptions, the maximum permissible range of rear brake fraction allowed, i.e. the "window" is given by,

$$0.0904 < R_r < 0.1733$$

for the example FWD vehicle without a physical test for brake balance certification. The "window" in brake balance is therefore 0.0829 or 8.29 percentage points in brake balance. This range is not sufficient to accommodate the anticipated vehicle brake balance variability (see Appendix 12, Variability) and so is unpracticable.

The current provisions of FMVSS 135 include a physical test for brake balance. Given the effect of such a physical test requirement described in Appendix 17, (Burnished Brake Performance), the current window in FMVSS 135 is given by

$$0.0904 < R_r < 0.1233$$

or a "window" of 3.29 percentage points in vehicle brake balance. Given that vehicle brake balance variability has been demonstrated to exceed 10 percentage points, the proposed provisions of FMVSS 135 must be modified.

For purposes of comparison, a similar analysis of the requirements of FMVSS 105 can be made. Even though FMVSS 105 does not specify a balance requirement, one can assume the maximum rear brake fraction is established by the LLV third effectiveness test of FMVSS 105. Using this condition, it can be shown that the upper limit on permissible rear braking is 0.2104 for the example FWD vehicle. Likewise, if one assumes the minimum rear brake fraction is established by the GVW second effectiveness test of FMVSS 105, then the minimum rear brake fraction is 0.1036. Thus, the "window" presently in FMVSS 105 is 10.64 percentage points in vehicle brake balance. The current provisions of FMVSS 135 therefore reduce the "window" in permissible brake balance by more than a factor of 3.

A similar analysis of ECE R13 and R.88 shows that both presently provide a "window" of 17.33 percentage points in vehicle brake balance. In order to reach some form of harmonization, one might have expected a "window" somewhere between the values provided in FMVSS 105 and ECE R13 or at least not less than that in FMVSS 105.

Preserving the current FMVSS 105 "window" in FMVSS 135, absent a physical test for brake balance certification would result in a burnished brake stopping distance of 249.8 feet at 100 km/h for GVW loading condition. Including an additional correction for the reduced number of attempts permitted,(see Appendix 15, Number of Attempts Allowed) yields an FMVSS 105 equivalent requirement of 253 feet. This may be compared to the current proposal of ECE R.88 where a burnished brake stopping distance of 252.6 feet is specified.

Thus, adopting the current burnished brake stopping distance requirement of R.88 is essentially equivalent to FMVSS 105 when the change in brake balance emphasis and the reduced number of attempts permitted are properly recognized. The increased stopping distance of R.88 is not a relaxation of the requirements but an adjustment consistent with the emphasis on vehicle brake balance. To preserve the specific vehicle test for brake balance certification will require a larger increase in the burnished brake stopping distance during the laden test,(see Appendix 17, Burnished Brake Performance).

The final version of FMVSS 135, to be viable as a worldwide braking standard, will have to provide sufficiently long stopping distances to allow a window of brake balance that can be met with production brake systems.

TIRE TO ROAD COEFFICIENT

OBJECTIVE

The purpose of this Appendix is to provide the GM views and supporting data regarding the proposed FMVSS 135 provisions for test road surface and the effect of tire to road coefficient of friction on braking performance.

CONCLUSIONS

1. The test road surface must be defined by peak tire-road coefficient rather than slide coefficient (Skid Number, SN) to be appropriate within FMVSS 135, a brake standard that does not permit wheel slide.

2. To provide accurate results, peak tire-road coefficient must be measured with a control tire which is representative of current construction, tread design and compounding technology as used on vehicles to be subject to FMVSS 135. The current control tire incorporated within FMVSS 105 and FMVSS 135 is not appropriate for this use because its construction and compounding technology is not representative of current production tires.

3. The technology of artificial road surfaces, as investigated in North America, has not progressed sufficiently for such a surface to be used as a substitute for road surfaces which are in general use by the motoring public.

4. The real world variability in road surface friction due to temperature, weather, and usage is inevitable and must be considered in any assessment of vehicle brake performance.

RECOMMENDATIONS

1. NHTSA should establish a specification for the road test surface based on an appropriate level of tire-road dry peak coefficient of friction using the new control tire rather than the current practice specified in FMVSS 105 which specifies the dry slide coefficient obtained by using the old technology ASTM control tire. Further, NHTSA should consider adopting the new ASTM traction control tire for measurement of the coefficient of friction of test road surfaces using the ASTM procedure E 274-70.

2. NHTSA should encourage, and help coordinate, international research efforts to improve technology for quantifying road traction coefficient and its contribution to braking traction. This effort should include an investigation of the current traction measurement procedures used by the motor vehicle and tire industries as well as the procedures developed by the International Standards organization (ISO), referenced in the Draft technical report 8349.

3. NHTSA should encourage and help coordinate a joint vehicle, tire, and road construction industry effort to investigate methods of quantifying the road surface traction characteristics. This effort should include investigation of the methods developed by the ISO which are referenced in the ISO Draft Technical report 8350 and should incorporate evaluation of the current technology traction control tire developed by the ASTM E 17 Committee (American Society for Testing and Materials Committee on traveled Surface Characteristics).

DISCUSSION

While literature exists to document nearly a century of research work on the quantification of road friction, this work has been characterized by at least two major problems.

1. The contribution of the road surface to friction has never been cleanly separated from the tire's contribution.

2. The interests and constraints associated with various parts of the transportation community vary. Highway people are interested in an economical approach to measurement that has long term stability and they are willing to sacrifice precision and resolution capability in order to identify large changes in road performance that may occur over many years of usage. Vehicle and tire engineers have less need for information regarding long term change, but need an approach that provides accurate data and is capable of detecting small differences in performance. The current government regulations for braking performance, fuel economy, uniform tire quality grading, etc. dictate that the vehicle and tire industries must account for small differences in tire-road coefficient of friction and must be able to quantify their effect on various characteristics of vehicle performance.

Many of the traditional approaches to road friction testing involve devices that are very crude approximations of a rolling tire. They are justified by their convenience and capacity to identify gross differences in friction characteristics.

The real measure of the road's contribution to dry traction probably relates to the statistics of its micro-topography, some chemical phenomena, and wear products that result from usage. Research has not been concentrated on obtaining relevant data because the priority of obtaining such information does not correspond to the near term needs of the highway or the automotive industry.

Peak Traction Versus Slide Traction

Figure 1 shows a typical plot of tire tractive force data, expressed as a friction coefficient, and plotted as a function of longitudinal slip. The difference between peak and sliding traction as illustrated is representative of that encountered with modern tires on road surfaces used for brake testing. For production tire configurations, all FMVSS brake testing must be accomplished in the area below 10% slip if wheel lockup is not to occur. To achieve the optimum stopping distance performance, the driver-vehicle combination must be operated as close to the peak tractive capability as possible.

The best stopping distance performance is achieved when the braking forces exerted reach the limit of tractive capability of the tires. Conversely, stopping distances increase when braking forces exceed tire tractive capability which occurs when they are skidding. In other words, a vehicle's best stopping distance performance is determined by tire-road maximum or peak coefficient of friction rather than the slide coefficient of friction. Figure 2 is included to show experimental data to support the conclusion that the stopping distance correlates with the peak coefficient of friction. These data were obtained with 60 mph stopping distance tests on three vehicles with different tire configurations. Peak traction of these tires was measured with an ASTM tire traction trailer in conjunction with these tests.

Standard Traction Reference Tires

FMVSS 105 specifies that road coefficient be measured with a sliding tire (100% slip) and specifies an ASTM standard traction reference tire developed primarily in response to the needs of the highway community. This is a bias-belted tire, developed over a decade ago, with a tread design representative of that in use during the 1960's.

Traction experts on ASTM E 17 and F 9 Committees are considering a proposal to update the reference tire design to make it more representative of current technology. This action is expected to result in the adoption of a new traction reference tire. General Motors has evaluated the proposed new ASTM control tire and found it to be acceptable as a control tire to measure tire-road coefficient of friction for the tire qualification programs. It will be necessary to update this tire in the future to keep abreast of changing tire technology and to provide appropriate data on tire-road traction characteristics.

The data shown in Figure 3 were obtained by measuring peak braking traction for several original equipment tires on number of public and Proving Ground roads. During this study, sliding traction of the traditional ASTM bias-belted reference tire was also measured. As can be seen from Figure 3, there is no correlation between the slide coefficient measurement of the ASTM tire and peak traction of original equipment tires on these surfaces. These data indicate that sliding friction measurements with a reference tire of this nature cannot be used to quantify the road peak traction.

<u>Artificial Road Surfaces, Specification and Measurement Methods</u>

In Notice 1 of the proposed FMVSS 135, NHTSA has invited comments on whether it should consider using the ISO procedures shown in Draft reports 8349 and 8350 in developing a specification of road surface in terms of peak coefficient. This is a conceptually appealing approach to resolving uncertainties regarding the test road by standardizing road formulation and construction technology. This idea has been explored by GM in the past and also investigated by the FHWA (Federal Highway Administration) and NHTSA during establishment of UTQG (Uniform Tire Quality grading) traction test track at San Angelo, Texas. GM work on artificial surfaces dates from the late 1960's and early 1970's. This work led to an artificial surface developed to achieve a wet coefficient of 0.3 for brake tests. This surface was developed by varying the width of stripes made of epoxy materials with two levels of wet sliding friction. This approach, which was very different from a real road surface, was found to be the best method available after extensive efforts with other techniques. The surface required frequent renewal and therefore was found to not provide a practical approach to achieving a suitable test road. Similar results were experienced by the FHWA in building a sand/epoxy surface at three different locations in North America. The resulting surfaces showed substantial differences in friction levels, as built, and very different rates of change in friction with usage and weathering.

GM considers inadequate, the approach to measurement of road friction and recommendations for artificial surfaces as discussed in the draft report resulting from the efforts of ISO TC 22-WG3. This document provides a compilation of very limited experience derived from highway, runway, and automotive research. Its approaches to measurement are not used in North America and are thought to be even less representative of real tire function than the current ASTM standard reference tire method discussed above. Recent meetings of automotive engineers in Europe indicate similar views may exist among those with a greater need for resolution capability and accuracy.

Further, NHTSA should recognize that the ISO Draft reports are preliminary and are not approved by the appropriate ISO committees. These draft reports are undergoing additional refinement in response to comments submitted by the appropriate U.S.A. technical advisory groups for ISO.

It is well known that GM developed an extensive set of tire specifications in the 1970's called the TPC (Tire Performance Criteria) specifications which include a section on wet and dry braking traction. Figure 4, taken from the TPC specifications, defines the surfaces used by GM and its tire suppliers for qualification of original equipment tires. This procedure employs specific road surfaces at the Automotive Proving Ground near Pecos, Texas referred in the attached Figures as "G4". These surface are available to GM and its suppliers for both tire development and qualification testing. Usage of a single facility in the Southwest is an expensive and cumbersome practice that would be quickly replaced if there was a viable alternative available.

<u>Road Surface Variability</u>

The above discussions on tire-road coefficient of friction and characteristics of the test road surfaces indicate that the stopping distance performance achieved for any brake system will vary depending on the road surface characteristics.

To demonstrate this variability GM has reviewed its data taken in monitoring road surface friction on its brake test surfaces, using the ASTM tire as specified in FMVSS 105. A scan of these data imply a range in peak traction of about 6 skid numbers over a period of four years. It is likely that variation in samples of control tires is responsible for part of this range. However, we are unaware of technology that provides significantly more repeatable test surfaces than that used by General Motors.

<u>Discussion of Recommendations</u>

The agency should assure itself that the test surface used for FMVSS testing has friction coefficient characteristics which are representative of typical public roads.

Figure 5 shows statistical data comparing two GM brake test road facilities at its Milford and Mesa Proving Grounds (labeled as 'S' and '105' respectively), with public roads in the same area, using representative burnished tires. A degree of variability in road surface friction due to temperature, weather, and usage is inevitable and must be considered in any assessment of a brake performance. GM recommends that data of this nature be used to establish a basis for a joint vehicle, tire, road construction industry/NHTSA/ASTM effort to develop better methods of quantifying test road surfaces.

Tire Braking Traction

Typical Measured Traction Force Curves at 40 MPH on Well Maintained Dry Asphalic Surface

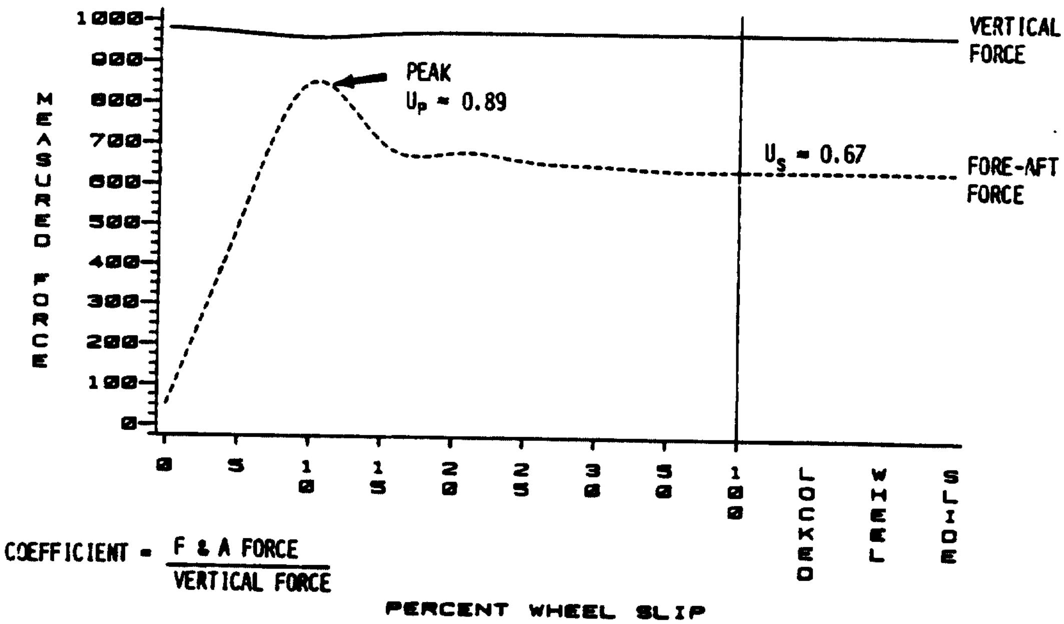


Figure 1

Stopping Distance vs Peak Traction

60 MPH Stopping Distance Tests (at DPG)

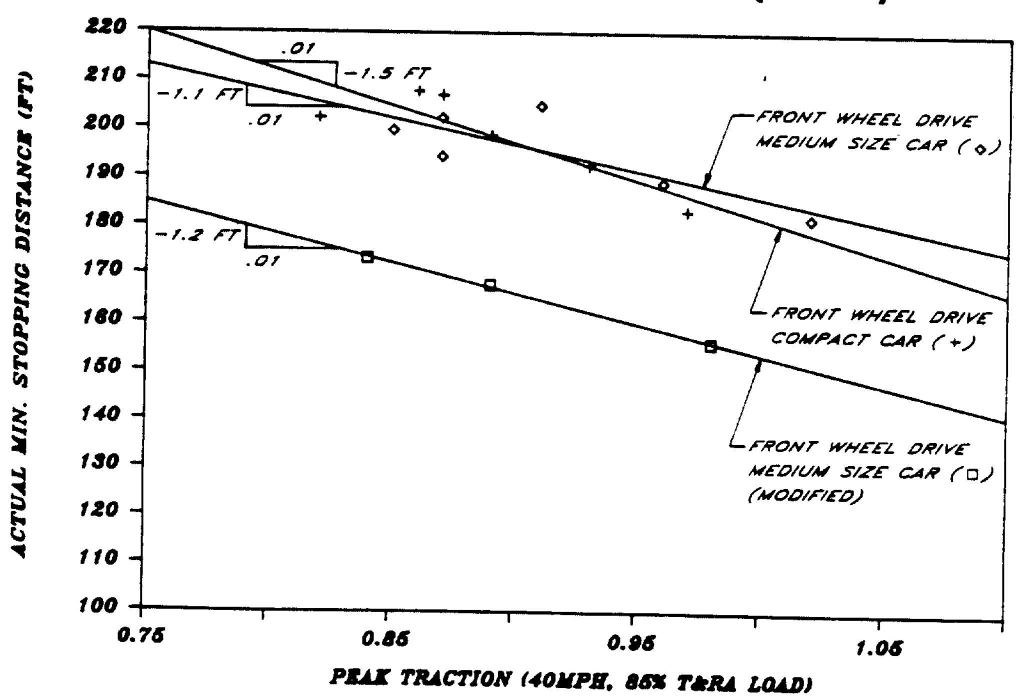


Figure 2

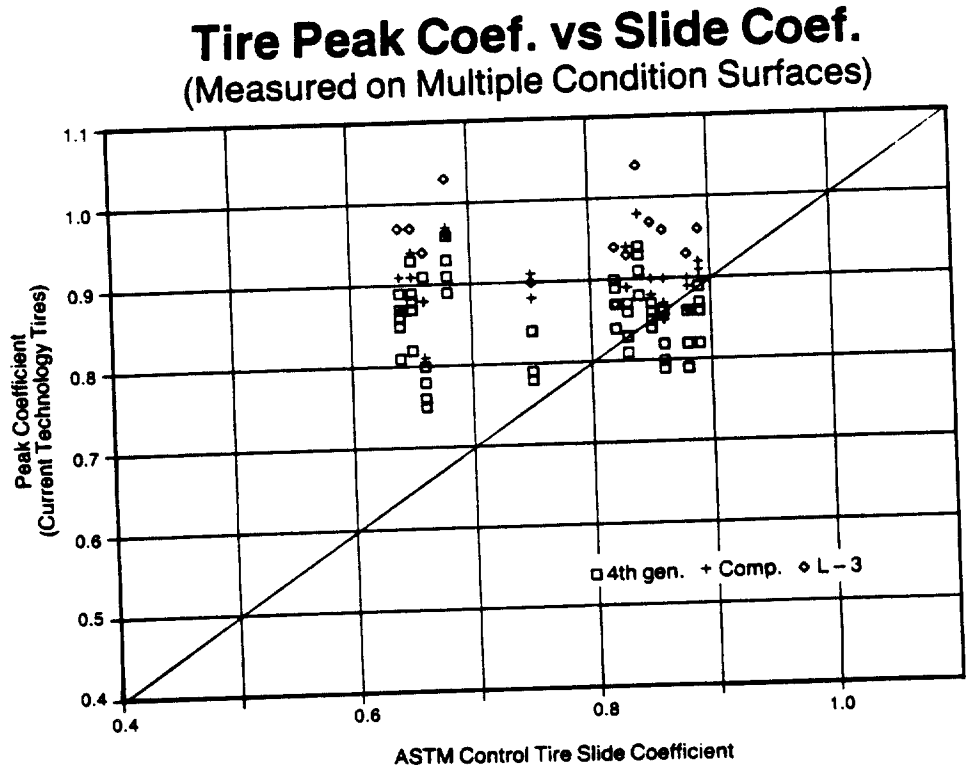


Figure 3

1.3.10 Test Surfaces: Braking traction tests for TPC qualification are conducted by General Motors on the following surfaces:

1.3.10.1 Dry test surface: A clean, level or slightly graded, well maintained coarse aggregate asphaltic concrete such as Michigan Highway Department 31-A or Texas Highway Department Type D road surface designation with ASTM E501 sliding skid number (dry) at 64 km/h 80. (This corresponds to surface 'S' at the Automotive Proving Grounds, Pecos, Texas.) See Appendix A.1 for Test Surface Preparation.

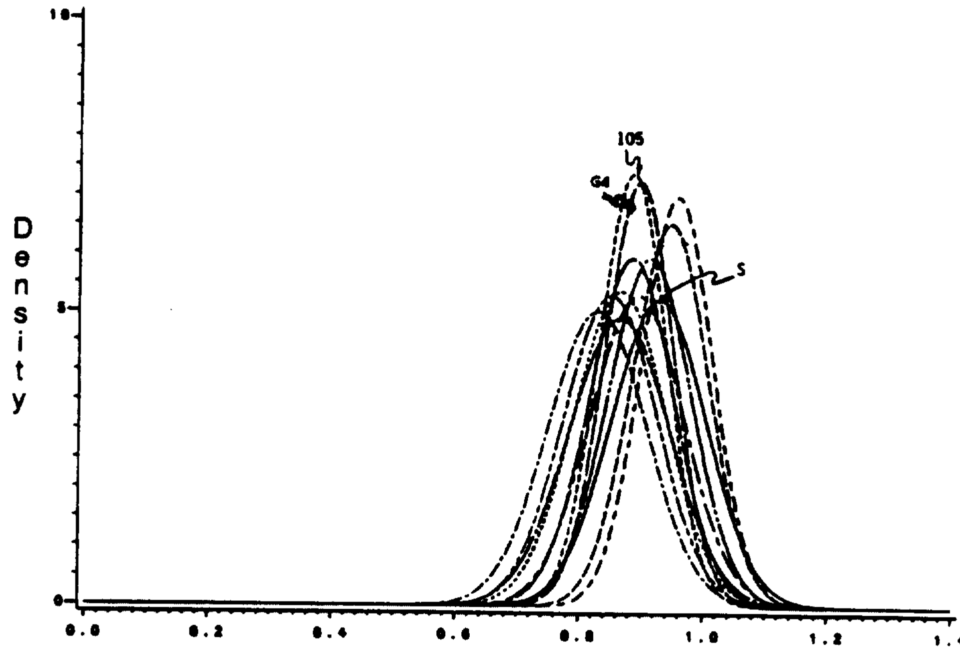
1.3.10.2 Wetted Test Surface: A clean, level or slightly graded, concrete or asphaltic concrete which has been constructed or modified to exhibit ASTM E501 wetted sliding skid number at 64 km/h ~ 30. (This corresponds to surface "G2" at the Automotive Proving Grounds, Pecos, Texas.) See Appendix A.1 for test surface preparation.

1.3.11 Wetted Surface Water Depth: For tests requiring wetted test surfaces, water shall be applied to a nominal depth of 1.25 mm ±0.25 mm above surface texture depth. See appendix A-1 for specific details of test surface water application.

Figure 4

GM Tire Assessment Program

Condition : Dry
Probability Density Function 40 MPH



Peak Coefficient
Complete Tire Matrix

Figure 5

TIRE DESIGN CONSIDERATIONS

OBJECTIVE

The purpose of this Appendix is to provide GM views and supporting data regarding the effect of tire-road peak dry traction coefficient on vehicle braking and fuel economy performance, as well as other tire dependent vehicle performance characteristics demanded by the consumer.

CONCLUSIONS

1. Both FMVSS 105 and the proposed FMVSS 135 constitute an indirect regulatory constraint on original equipment tire design.

2. A conflicting indirect regulatory constraint on original equipment tires results from Corporate Average Fuel Economy (CAFE) standards.

3. The direct conflict between peak dry traction and rolling resistance is inescapable with current domestic tire technology unless premium tread depth specifications and tire design practices of assuring acceptable performance for all driving conditions are compromised.

4. Peak dry traction is not the only variable on the list of tire performance attributes which affect vehicle performance. Dry and wet sliding traction, wet peak traction at high speeds, and snow traction also have significance.

5. NHTSA should recognize that tire-road peak dry traction coefficient of the current generation original equipment tires is in the range of 0.7 to 0.9 in setting the effectiveness and

brake balance requirements in the proposed FMVSS 135 brake standard. This lower than projected value for peak coefficient has the impact of increasing the stopping distances achievable during brake tests.

RECOMMENDATION

1. It is essential that the additional indirect regulations which are not applicable to the aftermarket tire industry, not mandate original equipment tire design compromises which cause significant conflict with consumer interests. The original equipment tire must be allowed to remain a viable competitor to other available tires.

2. The stopping distance performance requirements specified in FMVSS 135 should be modified to account for the lower than projected value of peak dry traction coefficient observed for original equipment tires.

3. NHTSA should recognize the potential adverse impact of increasing the peak dry traction on both fuel economy (CAFE) as well as tire dependent vehicle performance characteristics demanded by the consumer such as tread life and wet/snow traction.

DISCUSSION

The stopping distances achieved on any brake test are influenced by driver ability, characteristics of the test road surface, and tire to road coefficient of friction. Tires have a major influence on brake results since tire-road peak traction dictates the level of deceleration which is attainable before wheel lock occurs.

Braking performance for the test procedures in FMVSS 105 and the proposed FMVSS 135 is tire dependent. Moreover, such tests are less stringent for vehicles fitted with tires exhibiting very high peak dry traction characteristics than for vehicles fitted with tires with lower coefficient.

To demonstrate the tires contribution to vehicle braking performance, General Motors conducted stopping distance tests using the FMVSS 135 procedure for the same vehicle and brake system fitted with tires having two different levels of peak dry traction. The first test was conducted with original equipment (OE) production tires having peak coefficient values in the range of 0.7 to 0.9, while the second test was conducted with non-production 'sticky' tires having peak coefficients over 1.0. These 'sticky' tires are considered unacceptable for wear, snow traction and rolling resistance, but they were tested to illustrate the effect of dry peak traction on stopping distance. These test results showed an average increase of about 13% in pass margin using the high peak coefficient 'sticky' tires over OE tires. Table 1A AND 1B show the detailed results of this evaluation.

Modern tire design technology has the capability for producing tires with very high levels of peak dry traction when other tire performance attributes are assigned less priority. One of the key performance attributes that is nearly always sacrificed in a high traction tire is the reduced rolling resistance which is important to fuel economy. Figure 1 presents the history of rolling resistance improvements achieved with production tires over nearly two decades of development that emphasized the role of tires relative to fuel economy. Figure 1a presents the relationship between the tire's peak dry traction coefficient and its rolling resistance in Newtons(N), measured on the 1.7 Meter Wheel and Twin Roll rolling resistance test machine that is most commonly used for studying tire dependent vehicle fuel economy effects. Figure 1b presents the relationship between the tire rolling resistance and fuel economy in terms of the change in miles per gallon (MPG) at various levels of MPG ratings. These data indicate that for a 25 MPG base vehicle, approximately 0.1 mile per gallon increase in fuel economy would be achieved with a 1 Newton reduction in tire rolling resistance. Table 2 shows the importance of these tire rolling resistance improvements in terms of miles per gallon for vehicles sold in North America. These improvements have played a key role in industry efforts to achieve compliance to NHTSA fuel economy standards in a manner which is appropriate to minimizing total transportation costs. Some of these improvements have resulted from developing vehicle structure and chassis characteristics around higher tire inflation pressures, but a substantial part of this improvement is associated with rubber compounding for reduced rolling energy loss. Unfortunately, these low energy loss compounds tend to produce tires with lower peak dry traction as shown in Figure 2. During this same development phase, the wet traction has been improving steadily as shown in Figure 3. This has been achieved in part by the specification of premium tread depths and more sophisticated tread designs developed by the tire industry.

The reduction in peak dry traction of Figure 2 has occurred gradually over a period of years. Attempts to track these small changes with minimum stopping distance tests were often unsuccessful due to variability in vehicles and driver skills. Even the tire traction test data history has a degree of uncertainty associated with control tire technology. The effect of this gradual reduction in peak traction has been to increase the difficulty in meeting the requirements of the FMVSS 105.

Many studies of tire tread rubber compounding show a direct contrast between traction and rolling resistance. It has been clear for some time that a tread rubber compounding or tire construction breakthrough is needed to decouple these attributes. Tire research indicates some promising direction for the future, but these compounds will not be available for domestic production for some years.

The rolling resistance/dry traction compromise can also be altered by specifying tires manufactured with reduced tread depth. Such tires have lower rolling resistance because less rubber is being flexed as the tire rolls and they can use higher dry traction compounds for equivalent rolling resistance. Most GM cars have been produced with original equipment tires designed at a "premium tire" tread depth since the early 1970's. Many competitive cars are marketed in North America with tires having less than premium tread depths. Reduced tread depth tires generally have reduced driving traction in snow and may have reduced wet traction for high speeds and poorly drained roads. These tires can also exhibit reduced wear life and GM surveys show this factor to be important to the consumer. It was a dominant factor in consumer surveys at the time when premium tread depth tires were being developed for original equipment usage.

Before premium tread depth tires were first introduced as original equipment, GM had many consumer complaints resulting from dealer substitution of after market premium tread depth tires on new cars. Many of these tires were built to different specifications for balance, vibration related uniformity, snow traction, and full load durability. The consumer and service industry were experiencing great difficulty in tracing various vibration and other vehicle problems to these non-original equipment tires. Use of carefully specified premium tread depth tires as original equipment has largely eliminated this problem. General Motors believes that an effort to harmonize brake standards should not dictate a return to reduced tread depth tires as original equipment, a move that very likely would cause a return to the customer or dealer tire exchange problems as indicated above.

It must be recognized that focusing on tire-road peak dry traction at the expensse of other performance characteristics would be mainly important to artificial driving situations, like FMVSS brake testing. A few trained and skilled drivers can use improved dry peak tire-road traction to reduce stopping distances in emergencies or reduce precrash kinetic energies associated with accidents because they are able to modulate brake application to appropriate levels. However, most American drivers faced with severe stopping situations fully apply the brakes to cause four wheel lock up. Therefore, sliding friction for dry, wet, and snow conditions will actually be more important to the vast majority of drivers.

General Motors has been conducting a "Tire Traction Assessment Program" to gain better understanding of the actual traction conditions experienced by consumers. Figure 4 provides an indication of the spectrum of traction conditions thought to exist on public roads, assuming average tires. Peak dry traction on a high friction surface represents a single situation that may be rarely encountered by the consumer.

Figures 5 and 6 provide information on the wide range of wet friction conditions that exist on public roads, and demonstrate the need to understand this aspect of tire-road traction.

TABLE 1A

STOPPING DISTANCE IN FMVSS 135

TEST CONDITION	TEST REQUIREMENT (Feet/Meters)	O.E. TIRES (ft/m)	'STICKY' TIRES (ft/m)
Pre-burnish	236 / 72	224 / 68	197 / 60
Cold eff. (post 36)	214 / 65	217 / 66	194 / 59
Cold eff. (post 86)	214 / 65	224 / 68	179 / 55
High speed, GVW	416 / 127	409 / 125	341 / 104
High speed, LLV	416 / 127	339 / 103	268 / 82

TABLE 1B

STOPPING DISTANCE IN FMVSS 105

TEST PORTION	SPEED (mph/kmh)	LOADING	TEST REQUIREMENT (Feet/Meters)	O.E. TIRES (ft/m)	'STICKY' TIRES (ft/m)
First eff.	30 / 48	GVW	57 / 17	49 / 15	43 / 13
	60 / 96	GVW	216/ 65	197/ 60	168/ 51
Second eff.	30 / 48	GVW	54 / 16	46 / 14	44 / 13
	60 / 96	GVW	204/ 64	191/ 58	173/ 53
	80 / 128	GVW	383/ 115	366/ 111	317/ 97
Third eff.	60 / 96	LLV	194/ 58	162/ 49	140/ 43
Partial	60 / 96	LLV	456/ 137	344/ 105	296/ 90
				366/ 111	292/ 89
		GVW	456/ 137	418/ 128	358/ 109
				442/ 135	353/ 108
Failed boost.	60 / 96	GVW	456/ 137	340/ 104	287/ 86
Fourth eff.	30 / 48	GVW	57 / 17	47 / 14	45 / 14
	60 / 96	GVW	216/ 65	194/ 59	167/ 51
	80 / 128	GVW	405/ 122	353/ 108	311/ 95
	100/ 160	GVW	673/ 202	555/ 169	499/ 152

Fuel Economy Improvements Due To Rolling Resistance

	25 MPG Vehicle		35 MPG Vehicle	
	MPG	Delta MPG	MPG	Delta MPG
1968 Technology	25.0	0	35.0	0
1975 Technology	26.0	1.0	37.1	2.1
1986 Technology	28.0	3.0	41.2	6.2

Table 2

General Motors Original Equipment Tire Rolling Resistance History Including 4th Generation TPC Tires

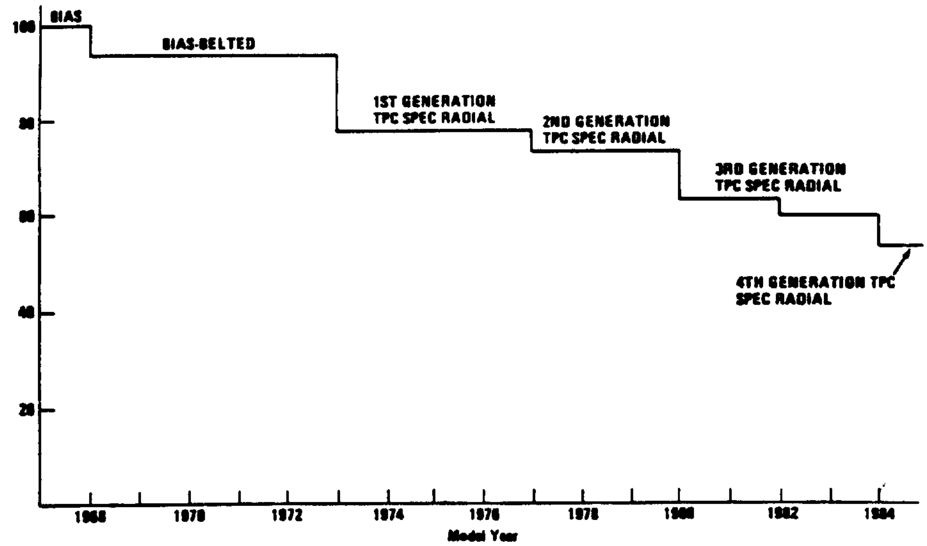


Figure 1

4th Generation Compound Study

RR/Traction Trade-Offs (P195/75R14)

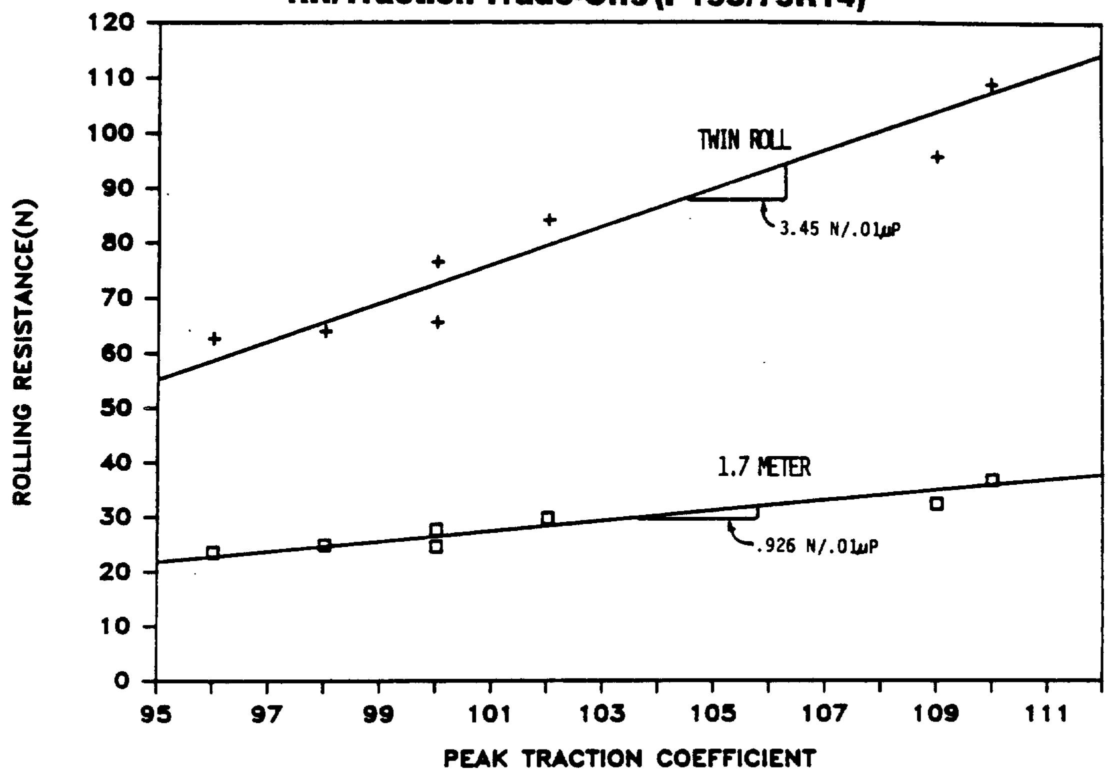


Figure 1A

Effects of Rolling Resistance on Fuel Economy

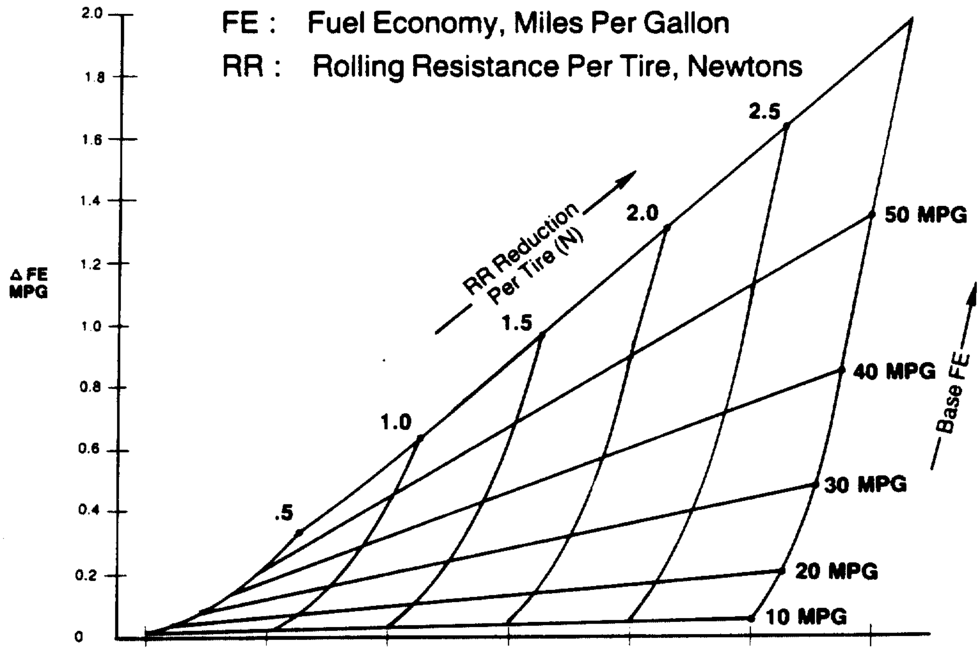


Figure 1B

1978 — 1985 Dry Traction History

(O.E. Base Tires as Measured on APG Surface "S") 40 MPH

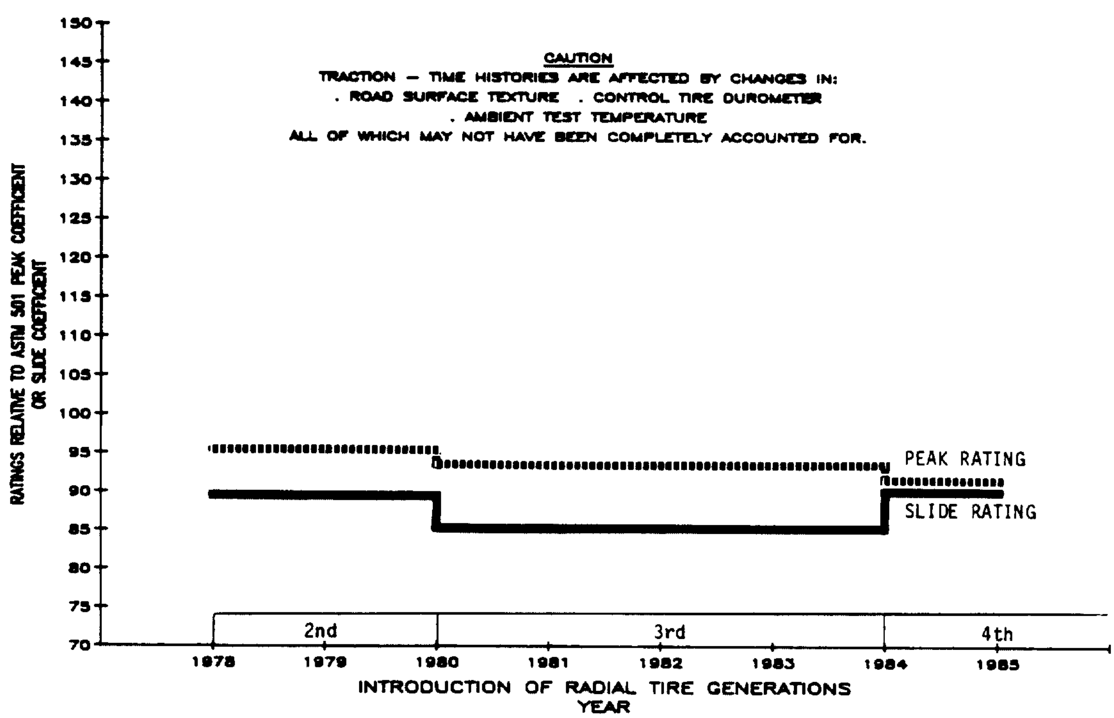


Figure 2

1978 — 1985 Wet Traction History

(O.E. Base Tires as Measured on APG Surface "G2")
60 MPH Water Depth 0.05 in.

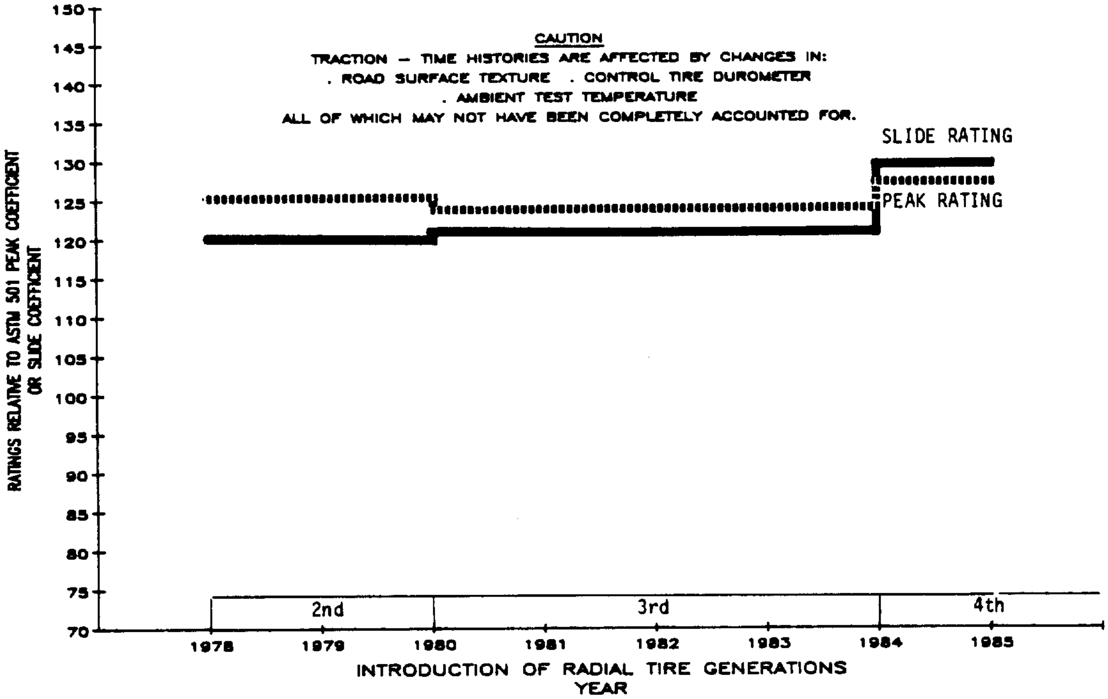


Figure 3

Tire Braking Traction Profile

Tire Friction vs Surface Conditions
(Simulation)

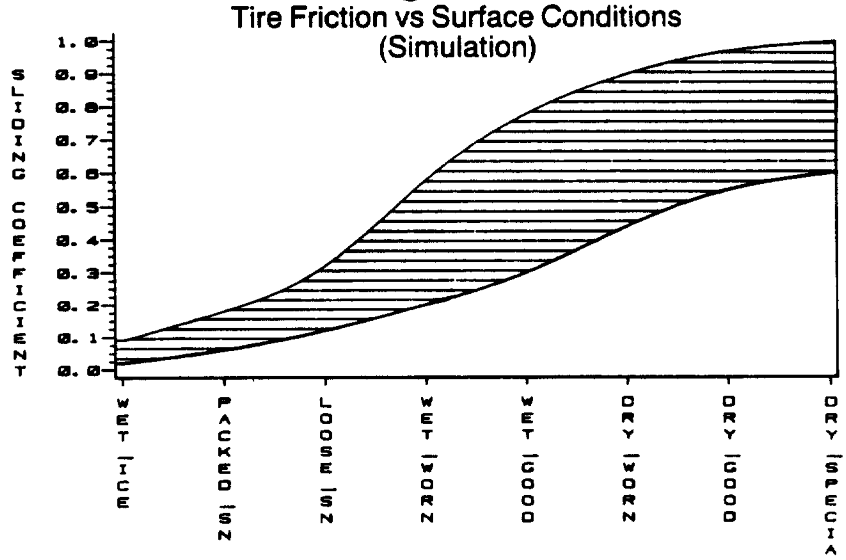


Figure 4

GM Tire Traction Assessment Program

Condition : 0.04 Inches Water
Probability Density Function

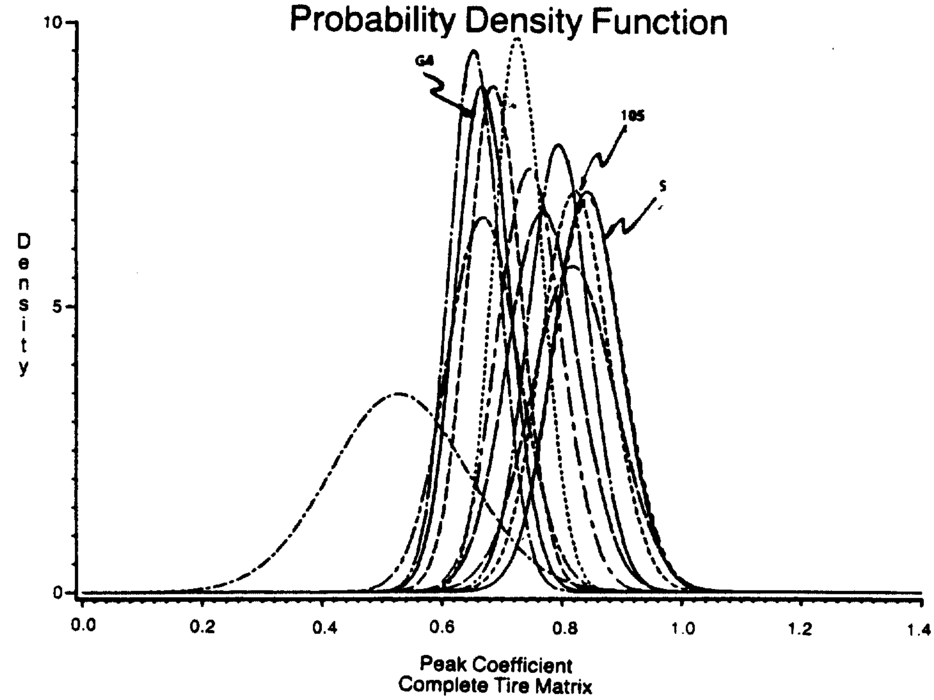


Figure 5

GM Tire Traction Assessment Program

Condition : 0.04 Inches Water
Probability Density Function

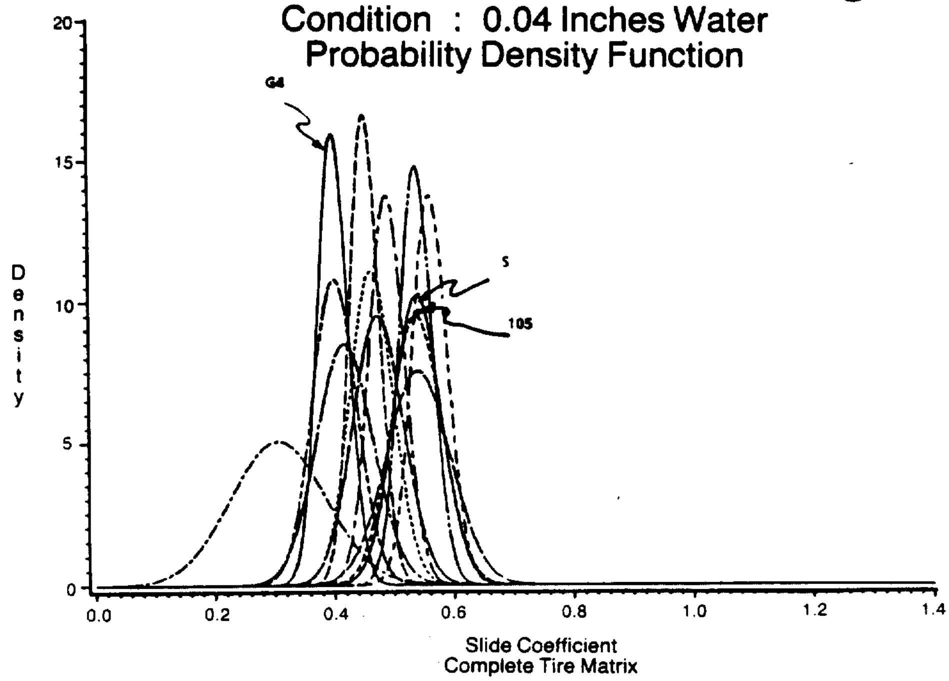


Figure 6

GM TEST PROGRAM

OBJECTIVE

The purpose of this Appendix is to review test data from the Test Program GM conducted to determine the performance capability of vehicles meeting the requirements of FMVSS 105 when tested to the proposed procedure of FMVSS 135.

CONCLUSIONS

1. Most vehicles currently meeting the performance requirements of FMVSS 105 and ECE R13 are not capable of meeting all of the requirements of FMVSS 135.

2. Stopping distance performance of current production vehicles is limited by tire-road peak traction.

3. Stopping distances achieved using either FMVSS 105 or FMVSS 135 are reduced when a set of special purpose tires with higher dry peak traction is used.

4. A significant difference in the brake balance is observed between measurements taken at the beginning and the end of the FMVSS 135 test sequence.

RECOMMENDATIONS

1. NHTSA should establish stopping distance requirements consistent with the capability of current production brake systems and tires.

2. The adhesion utilization requirement should be established using the calculation approach as used in the ECE R13

regulation. However, if the agency desires to specify a vehicle test for the adhesion utilization require ment, then it should be placed at the end of FMVSS 135 test sequence.

INTRODUCTION

GM has conducted an extensive test program for purposes of preparing its response to FMVSS 135. In both the docket, and at the October, 1985 GRRF meeting in Dearborn, Michigan, the agency specifically requested that manufacturers provide comments supported by test data or analysis. The test program described here was conducted to address this agency request.

GM response is based on the results from a total of more than 600 vehicle tests, including 57 vehicle tests conducted to address the issues of FMVSS 135. The testing included 16 stopping distance tests, 12 adhesion utilization tests, 9 brake burnish evaluation tests, 8 fade schedule assessment tests, 6 instrumented vehicle descents at Pikes Peak and 6 fully instrumented tests for variability to complement the 549 vehicle tests previously conducted to assess the variability. This section of the GM response will focus only upon the 16 stopping distance tests with the intent of comparing vehicle performance in FMVSS 105 and the proposed FMVSS 135 tests. GM comments based on the results of the adhesion utilization, brake burnish, fade and recovery tests are included in the Appendices 13, 10, 25, 26, and 27 respectively.

The 16 stopping distance tests of front and rear wheel drive vehicles included 7 tests to the procedure of FMVSS 105 and 9 to the procedure of FMVSS 135. Twelve of these tests were conducted with full vehicle instrumentation including torque wheels, line pressure transducers, wheel speed and wheel revolution indicators, pedal force transducers, and an on board vehicle decelerometer in addition to the standard stopping distance test hardware (distance totalizer and retentative speedometer). Each vehicle test was started with new brake hardware, and new tires. Since these tests were conducted with torque wheels, adhesion utilization (brake balance) information was available for each stop and, therefore, the single axle procedure itself was not run within these tests. GM comments regarding the single axle test are contained in Appendix 13, Adhesion Utilization Assessment Tests.

Spike stops, which typically destroy test tires, were eliminated from the test sequence because subsequent traction trailer tests of all tires were an integral part of the "Tire Traction Profile Study" which is discussed in detail in Appendix 11, Tire Burnish. Water recovery stops in FMVSS 105 were not run so as to avoid damage to the vehicle torque wheels and slip ring assemblies. Several tests were run without evaluating static park brake performance since little if any energy is delivered to the brake system in this test.

DISCUSSION

FMVSS 105 Test Results

Test summaries for the FMVSS 105 tests conducted are shown in tables 1-7. The test summaries include each test requirement, the actual performance attained, the pass (fail) margin in %, and the upper and lower pedal forces encountered during each test phase.

Table 1 contains the test results for the 1985 RWD vehicle equipped with semi-metallic front brake friction materials and asbestos rear brake friction materials. For this particular vehicle test, the parking brake test was not run. This vehicle successfully completed all FMVSS 105 test requirements that were evaluated, with the smallest margins encountered in the partial system tests where the vehicle was traction limited in the LLV condition and pedal force limited in the GVW condition. This condition was encountered during the rears only portions of the FMVSS 105 partial system test of this front/rear split system equipped vehicle.

Table 2 contains the test summary for the 1985 FWD vehicle equipped with semi-metallic front disc brake friction materials and asbestos rear drum brake friction materials. This vehicle has a diagonal split brake system, and met all FMVSS 105 test requirements evaluated.

Table 3 contains the summary of results for the 1985 RWD vehicle equipped with asbestos front disc brake friction materials and asbestos rear drum brake friction materials. Again, the vehicle successfully completed all the FMVSS 105 test requirements evaluated.

Table 4 shows the results of a repeat test of the vehicle evaluated in Table 2 except LLVW park brake test was added.

Table 5 contains the summary of results for the 1985 FWD vehicle with a lower output rear asbestos lining, and all other vehicle parameters equivalent to the tests shown in Table 2 and 4. This test was run to study the impact of a rear lining change to slightly increase the degree of front bias as if the the adhesion utilization requirements of FMVSS 135 have to be met with a physical test. Comparison of the results in Tables 2, 4, and 5 show all FMVSS 105 test requirements were met by the FWD test vehicle, with the exception of the park brake requirement at GVW with the lower output rear lining.

Table 6 contains the summary of results for a four wheel disc brake version of the 1985 FWD vehicle. This vehicle employs a diagonally split hydraulic system and was equipped with wide, high performance tires. The pass margins are generally higher than those achieved with the disc/drum versions of the FWD vehicle, equipped with the current technology low rolling resistance, all season tires.

Table 7 contains the summary of results of a retest for the FWD vehicle described in Table 5 except high dry peak traction tires made of a modified tread compound were used. The purpose of this test was to investigate the effect of tire peak traction on stopping distance. The stopping distance results obtained with both tires can be made by comparing the results shown in Tables 5 and 7. This comparison is shown in Table 8. These results show the impact of tire peak traction on stopping distance and also strongly suggest that most vehicles are both traction and brake balance limited.

FMVSS 135 Test Results

The stopping distance results of the 9 GM vehicle tests to the FMVSS 135 procedure are shown in Tables 9-17.

Table 9 shows the stopping distances and the pass (fail) margins of the RWD vehicle with semi-met front disc brake friction materials and asbestos rear drum brake lining materials when the short burnish (36 stop) and 80 snub fade options of FMVSS 135 were used. The results in Table 9 may be compared to the FMVSS 105 test results of this same vehicle shown in Table 1. While this vehicle passed all portions of the FMVSS 105 test that were run, it failed several FMVSS 135 provisions including brake balance.

Table 10 contains the stopping distance results for the FWD vehicle in the FMVSS 135 procedure when the short burnish (36 stop) and 80 snub fade options were used. The results shown in Table 10 may be compared to those obtained in FMVSS 105 testing shown in Table 2. This vehicle failed the pre-burnished effectiveness and the static park brake provisions.

Table 11 shows the FMVSS 135 stopping distances obtained with the RWD vehicle equipped with asbestos front and rear brake friction materials. The long (86 stop) burnish procedure and the 15 snub fade options were used for this test. The FMVSS 135 test results shown in Table 11 may be compared to those obtained in the parallel FMVSS 105 test shown in Table 3. Again, this vehicle failed several test provisions including adhesion utilization.

Table 12 contains the stopping distance results for the FWD vehicle in FMVSS 135 when the long burnish (86 stop) and the 15 snub fade options were used. These may be compared to the FMVSS 105 results shown in Table 4. This vehicle met the adhesion utilization provision of FMVSS 135, yet failed several of the stopping distance criteria.

Table 13 shows the FMVSS 135 test results for the FWD vehicle with a slightly lower output rear brake lining and may be compared to the FMVSS 105 test results shown in Table 5.

Table 14 contains the summary of results of a retest for the FWD vehicle described in Table 13 except a special modified tread compound, high dry peak traction tires were used. The significant differences in the stopping distances achieved on these two tests confirms the impact of tire-road peak traction on vehicle stopping distance performance. As was shown in Table 8 for FMVSS 105 tests, the pass margins in FMVSS 135 are influenced by tires.

Table 15 contains the stopping distance results in FMVSS 135 for the four wheel disc version of the FWD vehicle equipped with a high peak traction tire developed for a high performance car. Even when equipped with this currently available O.E. tire, the vehicle fails to meet the hot stop and recovery effectiveness provisions of FMVSS 135.

Table 16 shows FMVSS 135 stopping distances obtained with a currently marketed manual brake equipped vehicle. This vehicle failed to comply with most of the performance provisions of FMVSS 135. Based on this test and analysis discussed elsewhere in the response, GM believes the current provisions of FMVSS 135 will preclude all manual brake systems in vehicles equipped with friction materials available in the domestic market.

Table 17 shows the stopping distances achieved with current anti lock brake system in a two passenger, high performance sports vehicle. This vehicle, which is nominally equipped with large size, high dry peak traction tires, does meet all FMVSS 135 provisions.

For completeness, and as a basis for comments offered in other portions of this response, average front and rear specific torques (corrected for holdoff pressure) for each vehicle configuration tested are shown in Figures 1-12. Front and rear brake specific torques are averaged at each speed in FMVSS tests.

Based on this extensive test program, several important observations can be noted. The first, and most important, is that contrary to the agency's stated intent, vehicles currently being built in compliance with FMVSS 105 and ECE R13 would not meet the provisions of FMVSS 135. In fact, as is pointed out elsewhere, the front axle limited brake balance provision of FMVSS 135 is in direct conflict with "equivalent" stopping distance provisions in FMVSS 105.

The second important observation to be made from this testing is that current technology, low rolling resistance tires, with tread designs and compounds optimized for dry, wet, snow and ice traction along with customer expectations for tire tread life simply do not allow compliance unless the requirements of FMVSS 135 are modified. As is shown by the GM testing, stopping distances are strongly influenced by tire-road dry peak traction. Shorter stopping distances are achievable in current configuration vehicles if they are equipped with compromised tire designs and tread compounds providing high dry peak traction.

With regard to burnish, the reasonably consistent difficulty in meeting pre-burnish and cold effectiveness requirements of FMVSS 135 suggests additional stops may be required to further condition not only the brakes, but also the tires on the test vehicle. Likewise, the continuing increase in tire peak traction during a certification test tends to make the final effectiveness requirement less meaningful (see Appendix 11, Tire Burnish and Appendix 28, Spike Stops and Final Effectiveness Tests).

In addition to the pre-burnished and cold effectiveness requirements, the test portions of FMVSS 135 evaluating hot performance, recovery, dynamic park brake, and no power performance were not met. With the exception of the manual brake vehicle, all vehicles met the final effectiveness requirement of FMVSS 135, although with less than desirable pass margin. The continued increase in tire peak traction throughout the FMVSS test, as well as the changes in foundation brake output (see Figures 1-12) all tend to make this requirement less meaningful.

With regard to foundation brake output, a cursory review of Figures 1-12 show, that specific torques are continuing to change throughout both the FMVSS 105 and FMVSS 135 test procedures. Part of this change is due to the different test speeds in FMVSS 105, but a majority of the difference observed is thought to be due to the continued burnishing of the brake system during the test. This behavior makes the placement of the adhesion utilization test within the certification procedure a critical concern. If a vehicle is to be evaluated with a physical test for brake balance, it probably should be placed last in the test sequence in order to provide the maximum conditioning to the brake system. Such placement in the test sequence will more faithfully emulate the brake balance of the vehicle in the hands of the customer over a majority of the vehicle's lifetime.

If the agency determines that a physical test for brake balance is needed, then the placement of the test procedure for brake balance within the harmonized schedule will be important. Since a statistically reliable and valid test procedure for brake balance has yet to be agreed upon by all the delegates to the GRRF, adopting the ECE R13 approach to adhesion utilization certification remains the most practical method available. (See Appendix 13, Adhesion Utilization Assessment Tests)

Perhaps the most important single technical finding from the extensive GM test program is that current technology vehicles are operating near the limit of adhesion of the tire-road interface in producing the stopping distances reported here. This is confirmed by the reduction in stopping distances which are observed when compromised tire configurations are used. This finding, when coupled with the theoretical limits of vehicle design and load range make it inevitable that stopping distances will have to be extended to accommodate a front axle limited brake balance requirement. This change in emphasis in the brake standard dominates the stopping distance capability of the vehicle, and as is shown elsewhere through rigorous analysis based on test data, requires longer stopping distances.

When stopping distances are finally established, the agency should recognize that sufficient pass margin over theoretical minimum must be afforded thereby to accommodate all influences so that manufacturers are assured of compliance. To require stopping distances that barely accommodate the theoretical maximum capability of the vehicle is different from the present performance requirements of FMVSS 105 (see Appendix 4, Brake Balance Influence on Stopping Distance).

Table 1

GM DATA REPORTS FOR THE FMVSS 105 TESTS

TEST NUMBER: T001V
DATE COMPL: 07/27/85
VEH: 85 RWD

TEST NAME	REQ. (ft)	PERF. (ft)	%PASS (-FAIL)	APPLY MIN	FORCE MAX
1ST EFF. - 30 mph	57	50.0	12.3 %	24	39
1ST EFF. - 60 mph	216	189.6	12.2 %	30	43
2ND EFF. - 30 mph	54	45.8	15.2 %	43	50
2ND EFF. - 60 mph	204	179.0	12.3 %	38	53
2ND EFF. - 80 mph	383	320.2	16.4 %	39	55
PARK BRAKE GVWR UP	**	NR	NR	NR	NR
PARK BRAKE GVWR DN	**	NR	NR	NR	NR
PARK BRAKE LLVW UP	**	NR	NR	NR	NR
PARK BRAKE LLVW DN	**	NR	NR	NR	NR
3RD EFF. - 60 mph	194	169.6	12.6 %	28	86
PARTIAL SYS 1 LLVW	456	450.8	1.1 %	13	116
PARTIAL SYS 2 LLVW	456	236.6	48.1 %	30	46
PARTIAL SYS 1 GVWR	456	428.4	6.1 %	7	150
PARTIAL SYS 2 GVWR	456	244.7	46.3 %	--	40
ANTILOCK	456	NA	NA	NA	NA
L.S.P.V.	456	NA	NA	NA	NA
NO POWER SYSTEM 1	456	371.5	18.5 %	125	145
NO POWER SYSTEM 2	456	NR	NR	NR	NR
1ST FADE BASELINE	*10	*10	NA	--	23
1ST FADE 1-5	*15	*15	NA	--	48
1ST FADE 6-10	*5-15	*15	NA	--	81
1ST FADE REC. 1-4	*10	*10	NA	--	40
1ST FADE REC. 5	*10	*10	NA	--	24
2ND FADE BASELINE	--	*10	NA	--	30
2ND FADE 1-10	*15	*15	NA	--	69
2ND FADE 11-15	*5-15	*15	NA	--	145
2ND FADE REC. 1-4	*10	*10	NA	--	37
2ND FADE REC. 5	*10	*10	NA	--	27
4TH EFF. - 30 mph	57	47.5	16.7 %	47	67
4TH EFF. - 60 mph	216	193.9	10.2 %	28	37
4TH EFF. - 80 mph	405	360.6	11.0 %	11	34
4TH EFF. - *** mph	***	577.8	14.1 %	19	46
WATER RECOVERY	NR	NR	NR	NR	NR
SPIKE STOPS	NR	NR	NR	NR	NR

*	Denotes Decelerations in ft/sec2
**	125 lb for Pedal; 72 lb for Hand
***	Requirements proscribed in FMVSS 105-4.1.1.5; Test Nos. 002V & 006V were stopped from 95 mph, the other were stopped from 100 mph
NA	Not Applicable
NR	Test Not Run
FWD	Front Wheel Drive
RWD	Rear Wheel Drive

Table 2

GM DATA REPORTS FOR
FOR FMVSS 105 TESTS

TEST NUMBER: 002V
DATE COMPL: 07/25/85
VEH: 85 FWD

TEST NAME	REQ. (ft)	PERF. (ft)	%PASS (-FAIL)	APPLY MIN	FORCE MAX
1ST EFF. - 30 mph	57	56.5	0.9 %	25	85
1ST EFF. - 60 mph	216	202.0	6.5 %	30	95
2ND EFF. - 30 mph	54	50.6	6.3 %	25	85
2ND EFF. - 60 mph	204	191.7	6.0 %	32	75
2ND EFF. - 80 mph	383	335.0	12.5 %	35	125
PARK BRAKE GVWR UP	**	NR	NR	NR	NR
PARK BRAKE GVWR DN	**	NR	NR	NR	NR
PARK BRAKE LLVW UP	**	NR	NR	NR	NR
PARK BRAKE LLVW DN	**	NR	NR	NR	NR
3RD EFF. - 60 mph	194	183.4	5.5 %	15	45
PARTIAL SYS 1 LLVW	456	324.9	28.8 %	15	65
PARTIAL SYS 2 LLVW	456	378.0	17.1 %	12	95
PARTIAL SYS 1 GVWR	456	404.1	11.4 %	13	110
PARTIAL SYS 2 GVWR	456	389.7	14.5 %	18	110
ANTILOCK	456	NA	NA	NA	NA
L.S.P.V.	456	NA	NA	NA	NA
NO POWER SYSTEM 1	456	366.7	19.6 %	125	145
NO POWER SYSTEM 2	456	NR	NR	NR	NR
1ST FADE BASELINE	*10	*10	NA	--	10
1ST FADE 1-5	*15	*15	NA	15	35
1ST FADE 6-10	*5-15	*15	NA	30	35
1ST FADE REC. 1-4	*10	*10	NA	10	20
1ST FADE REC. 5	*10	*10	NA	--	15
2ND FADE BASELINE	--	*10	NA	--	11
2ND FADE 1-10	*15	*15	NA	25	40
2ND FADE 11-15	*5-15	*15	NA	41	100
2ND FADE REC. 1-4	*10	*10	NA	20	30
2ND FADE REC. 5	*10	*10	NA	--	22
4TH EFF. - 30 mph	57	47.1	17.4 %	50	115
4TH EFF. - 60 mph	216	200.6	7.1 %	20	55
4TH EFF. - 80 mph	405	353.8	12.6 %	24	72
4TH EFF. - *** mph	***	538.6	11.3 %	20	49
WATER RECOVERY	NR	NR	NR	NR	NR
SPIKE STOPS	NR	NR	NR	NR	NR

* Denotes Decelerations in ft/sec2
** 125 lb for Pedal; 72 lb for Hand
*** Requirements proscribed in FMVSS 105-4.1.1.5; Test Nos. 002V & 006V were stopped from 95 mph, the other were stopped from 100 mph
NA Not Applicable
NR Test Not Run
FWD Front Wheel Drive
RWD Rear Wheel Drive

Table 3

GM DATA REPORTS FOR THE FMVSS 105 TESTS

TEST NUMBER: 005V
DATE COMPL: 08/20/85
VEH: 85 RWD

TEST NAME	REQ. (ft)	PERF. (ft)	%PASS (-FAIL)	APPLY MIN	FORCE MAX
1ST EFF. - 30 mph	57	46.6	18.2 %	17	129
1ST EFF. - 60 mph	216	183.9	14.9 %	26	83
2ND EFF. - 30 mph	54	42.2	21.9 %	34	145
2ND EFF. - 60 mph	204	182.3	10.6 %	29	132
2ND EFF. - 80 mph	383	328.7	14.2 %	37	129
PARK BRAKE GVWR UP	**	125 lb	YES	NA	NA
PARK BRAKE GVWR DN	**	125 lb	YES	NA	NA
PARK BRAKE LLVW UP	**	NR	NR	NR	NR
PARK BRAKE LLVW DN	**	NR	NR	NR	NR
3RD EFF. - 60 mph	194	169.3	12.7 %	34	128
PARTIAL SYS 1 LLVW	456	445.9	2.2 %	35	51
PARTIAL SYS 2 LLVW	456	217.3	52.3 %	36	76
PARTIAL SYS 1 GVWR	456	405.9	11.0 %	45	142
PARTIAL SYS 2 GVWR	456	236.6	48.1 %	41	83
ANTILOCK	456	NA	NA	NA	NA
L.S.P.V.	456	NA	NA	NA	NA
NO POWER SYSTEM 1	456	380.5	16.6 %	125	146
NO POWER SYSTEM 2	456	NR	NR	NR	NR
1ST FADE BASELINE	*10	*10	NA	--	--
1ST FADE 1-5	*15	*15	NA	--	--
1ST FADE 6-10	*5-15	*15	NA	--	--
1ST FADE REC. 1-4	*10	*10	NA	--	--
1ST FADE REC. 5	*10	*10	NA	--	--
2ND FADE BASELINE	--	*10	NA	--	--
2ND FADE 1-10	*15	*15	NA	--	--
2ND FADE 11-15	*5-15	*15	NA	--	--
2ND FADE REC. 1-4	*10	*10	NA	--	--
2ND FADE REC. 5	*10	*10	NA	--	--
4TH EFF. - 30 mph	57	42.6	25.3 %	50	138
4TH EFF. - 60 mph	216	184.3	14.7 %	20	101
4TH EFF. - 80 mph	405	352.4	13.0 %	17	47
4TH EFF. - *** mph	***	536.6	20.3 %	21	46
WATER RECOVERY	NR	NR	NR	NR	NR
SPIKE STOPS	NR	NR	NR	NR	NR

* Denotes Decelerations in ft/sec2
** 125 lb for Pedal; 72 lb for Hand
*** Requirements proscribed in FMVSS 105-4.1.1.5; Test Nos. 002V & 006V were stopped from 95 mph, the other were stopped from 100 mph
NA Not Applicable
NR Test Not Run
FWD Front Wheel Drive
RWD Rear Wheel Drive

Table 4

GM DATA REPORTS FOR THE FMVSS 105 TESTS

TEST NUMBER: 006V
DATE COMPL: 08/23/85
VEH: 85FWD

TEST NAME	REQ. (ft)	PERF. (ft)	%PASS (-FAIL)	APPLY MIN	FORCE MAX
1ST EFF. - 30 mph	57	53.6	6.0 %	30	133
1ST EFF. - 60 mph	216	196.2	9.2 %	40	98
2ND EFF. - 30 mph	54	46.9	13.1 %	30	135
2ND EFF. - 60 mph	204	184.3	9.7 %	24	125
2ND EFF. - 80 mph	383	344.0	10.2 %	27	124
PARK BRAKE GVWR UP	**	NR	NR	NR	NR
PARK BRAKE GVWR DN	**	NR	NR	NR	NR
PARK BRAKE LLVW UP	**	125 lb	YES	NA	NA
PARK BRAKE LLVW DN	**	125 lb	YES	NA	NA
3RD EFF. - 60 mph	194	172.8	10.9 %	20	40
PARTIAL SYS 1 LLVW	456	316.5	30.6 %	15	53
PARTIAL SYS 2 LLVW	456	327.0	28.3 %	15	84
PARTIAL SYS 1 GVWR	456	416.9	8.6 %	22	83
PARTIAL SYS 2 GVWR	456	399.2	12.5 %	28	90
ANTILOCK	456	NA	NA	NA	NA
L.S.P.V.	456	NA	NA	NA	NA
NO POWER SYSTEM 1	456	353.0	22.6 %	77	140
NO POWER SYSTEM 2	456	NR	NR	NR	NR
1ST FADE BASELINE	*10	*10	NA	--	16
1ST FADE 1-5	*15	*15	NA	18	30
1ST FADE 6-10	*5-15	*15	NA	30	30
1ST FADE REC. 1-4	*10	*10	NA	18	20
1ST FADE REC. 5	*10	*10	NA	--	11
2ND FADE BASELINE	--	*10	NA	--	10
2ND FADE 1-10	*15	*15	NA	15	25
2ND FADE 11-15	*5-15	*15	NA	25	30
2ND FADE REC. 1-4	*10	*10	NA	17	25
2ND FADE REC. 5	*10	*10	NA	--	12
4TH EFF. - 30 mph	57	50.8	10.9 %	80	143
4TH EFF. - 60 mph	216	194.7	9.9 %	20	82
4TH EFF. - 80 mph	405	344.9	14.8 %	22	95
4TH EFF. - *** mph	***	476.9	21.4 %	25	106
WATER RECOVERY	NR	NR	NR	NR	NR
SPIKE STOPS	NR	NR	NR	NR	NR

* Denotes Decelerations in ft/sec2
** 125 lb for Pedal; 72 lb for Hand
*** Requirements proscribed in FMVSS 105-4.1.1.5; Test Nos. 002V & 006V were stopped from 95 mph, the other were stopped from 100 mph
NA Not Applicable
NR Test Not Run
FWD Front Wheel Drive
RWD Rear Wheel Drive

Table 5

GM DATA REPORTS FOR THE FMVSS 105 TESTS

TEST NUMBER: 009V
DATE COMPL: 10/10/85
VEH: 85 FWD

TEST NAME	REQ. (ft)	PERF. (ft)	%PASS (-FAIL)	APPLY MIN	FORCE MAX
1ST EFF. - 30 mph	57	49.0	14.0 %	45	146
1ST EFF. - 60 mph	216	197.0	8.8 %	27	100
2ND EFF. - 30 mph	54	45.8	15.2 %	57	130
2ND EFF. - 60 mph	204	190.6	6.6 %	30	87
2ND EFF. - 80 mph	383	365.8	4.5 %	25	76
PARK BRAKE GVWR UP	**	125 lb	NO	NA	NA
PARK BRAKE GVWR DN	**	125 lb	YES	NA	NA
PARK BRAKE LLVW UP	**	125 lb	YES	NA	NA
PARK BRAKE LLVW DN	**	125 lb	YES	NA	NA
3RD EFF. - 60 mph	194	162.0	16.5 %	34	79
PARTIAL SYS 1 LLVW	456	344.1	24.5 %	27	75
PARTIAL SYS 2 LLVW	456	365.8	19.8 %	25	51
PARTIAL SYS 1 GVWR	456	418.4	8.2 %	25	59
PARTIAL SYS 2 GVWR	456	442.0	3.1 %	24	49
ANTILOCK	456	NA	NA	NA	NA
L.S.P.V.	456	NA	NA	NA	NA
NO POWER SYSTEM 1	456	340.0	25.4 %	80	142
NO POWER SYSTEM 2	456	NR	NR	NR	NR
1ST FADE BASELINE	*10	*10	NA	--	22
1ST FADE 1-5	*15	*15	NA	--	40
1ST FADE 6-10	*5-15	*15	NA	--	--
1ST FADE REC. 1-4	*10	*10	NA	--	25
1ST FADE REC. 5	*10	*10	NA	--	22
2ND FADE BASELINE	--	*10	NA	--	18
2ND FADE 1-10	*15	*15	NA	--	40
2ND FADE 11-15	*5-15	*15	NA	--	70
2ND FADE REC. 1-4	*10	*10	NA	--	25
2ND FADE REC. 5	*10	*10	NA	--	20
4TH EFF. - 30 mph	57	46.5	18.4 %	50	125
4TH EFF. - 60 mph	216	193.9	10.2 %	29	75
4TH EFF. - 80 mph	405	353.2	12.8 %	25	69
4TH EFF. - *** mph	***	554.7	17.6 %	29	80
WATER RECOVERY	NR	NR	NR	NR	NR
SPIKE STOPS	NR	NR	NR	NR	NR

* Denotes Decelerations in ft/sec2
** 125 lb for Pedal; 72 lb for Hand
*** Requirements proscribed in FMVSS 105-4.1.1.5; Test Nos. 002V & 006V were stopped from 95 mph, the other were stopped from 100 mph
NA Not Applicable
NR Test Not Run
FWD Front Wheel Drive
RWD Rear Wheel Drive

Table 6

GM DATA REPORTS FOR THE FMVSS 105 TESTS

TEST NUMBER: 010V
DATE COMPL: 11/05/85
VEH: 85 FWD (4 DISK)

TEST NAME	REQ. (ft)	PERF. (ft)	%PASS (-FAIL)	APPLY MIN	FORCE MAX
1ST EFF. - 30 mph	57	48.6	14.7 %	79	132
1ST EFF. - 60 mph	216	195.7	9.4 %	101	136
2ND EFF. - 30 mph	54	43.4	19.6 %	46	137
2ND EFF. - 60 mph	204	169.1	17.1 %	44	116
2ND EFF. - 80 mph	383	297.7	22.3 %	33	91
PARK BRAKE GVWR UP	**	124 lb	YES	NA	NA
PARK BRAKE GVWR DN	**	124 lb	YES	NA	NA
PARK BRAKE LLVW UP	**	118 lb	YES	NA	NA
PARK BRAKE LLVW DN	**	100 lb	YES	NA	NA
3RD EFF. - 60 mph	194	145.7	24.9 %	25	76
PARTIAL SYS 1 LLVW	456	307.0	32.7 %	25	38
PARTIAL SYS 2 LLVW	456	295.0	35.3 %	26	40
PARTIAL SYS 1 GVWR	456	339.3	25.6 %	26	36
PARTIAL SYS 2 GVWR	456	334.8	26.6 %	27	44
ANTILOCK	456	NA	NA	NA	NA
L.S.P.V.	456	NA	NA	NA	NA
NO POWER SYSTEM 1	456	299.4	34.3 %	112	141
NO POWER SYSTEM 2	456	NR	NR	NR	NR
1ST FADE BASELINE	*10	*10	NA	--	21
1ST FADE 1-5	*15	*15	NA	--	39
1ST FADE 6-10	*5-15	*15	NA	--	110
1ST FADE REC. 1-4	*10	*10	NA	--	24
1ST FADE REC. 5	*10	*10	NA	--	19
2ND FADE BASELINE	--	*10	NA	--	20
2ND FADE 1-10	*15	*15	NA	--	45
2ND FADE 11-15	*5-15	*15	NA	--	78
2ND FADE REC. 1-4	*10	*10	NA	--	20
2ND FADE REC. 5	*10	*10	NA	--	24
4TH EFF. - 30 mph	57	41.5	27.2 %	59	128
4TH EFF. - 60 mph	216	158.5	26.6 %	32	106
4TH EFF. - 80 mph	405	266.5	34.2 %	39	123
4TH EFF. - *** mph	***	431.5	35.9 %	52	133
WATER RECOVERY	NR	NR	NR	NR	NR
SPIKE STOPS	NR	NR	NR	NR	NR

* Denotes Decelerations in ft/sec2
** 125 lb for Pedal; 72 lb for Hand
*** Requirements proscribed in FMVSS 105-4.1.1.5; Test Nos. 002V & 006V were stopped from 95 mph, the other were stopped from 100 mph
NA Not Applicable
NR Test Not Run
FWD Front Wheel Drive
RWD Rear Wheel Drive

Table 7

GM DATA REPORTS FOR THE FMVSS TESTS		TEST NUMBER: 014 DATE COMPL: 11/13/85 VEH: 85 FWD w/ G.Y.-GT/S			
TEST NAME	REQ. (ft)	PERF. (ft)	%PASS (-FAIL)	APPLY MIN	FORCE MAX
1ST EFF. - 30 mph	57	43.2	24.2 %	79	132
1ST EFF. - 60 mph	216	167.7	22.4 %	101	136
2ND EFF. - 30 mph	54	44.1	18.3 %	46	137
2ND EFF. - 60 mph	204	173.1	15.1 %	44	116
2ND EFF. - 80 mph	383	316.7	17.3 %	33	91
PARK BRAKE GVWR UP	**	125 lb	YES	NA	NA
PARK BRAKE GVWR DN	**	125 lb	YES	NA	NA
PARK BRAKE LLVW UP	**	125 lb	YES	NA	NA
PARK BRAKE LLVW DN	**	100 lb	YES	NA	NA
3RD EFF. - 60 mph	194	140.0	27.8 %	25	76
PARTIAL SYS 1 LLVW	456	296.1	35.1 %	25	38
PARTIAL SYS 2 LLVW	456	292.4	35.9 %	26	40
PARTIAL SYS 1 GVWR	456	358.1	21.5 %	26	36
PARTIAL SYS 2 GVWR	456	352.6	22.7 %	27	44
ANTILOCK	456	NA	NA	NA	NA
L.S.P.V.	456	NA	NA	NA	NA
NO POWER SYSTEM 1	456	283.6	37.8 %	112	141
NO POWER SYSTEM 2	456	NR	NR	NR	NR
1ST FADE BASELINE	*10	*10	NA	--	21
1ST FADE 1-5	*15	*15	NA	--	39
1ST FADE 6-10	*5-15	*15	NA	--	110
1ST FADE REC. 1-4	*10	*10	NA	--	24
1ST FADE REC. 5	*10	*10	NA	--	19
2ND FADE BASELINE	--	*10	NA	--	20
2ND FADE 1-10	*15	*15	NA	--	45
2ND FADE 11-15	*5-15	*15	NA	--	78
2ND FADE REC. 1-4	*10	*10	NA	--	20
2ND FADE REC. 5	*10	*10	NA	--	24
4TH EFF. - 30 mph	57	44.8	21.4 %	59	128
4TH EFF. - 60 mph	216	167.0	22.7 %	32	106
4TH EFF. - 80 mph	405	311.3	23.1 %	39	123
4TH EFF. - *** mph	***	498.7	25.9 %	52	133
WATER RECOVERY	NR	NR	NR	NR	NR
SPIKE STOPS	NR	NR	NR	NR	NR

* Denotes Decelerations in ft/sec2
** 125 lb for Pedal; 72 lb for Hand
*** Requirements proscribed in FMVSS 105-4.1.1.5; Test Nos. 002V & 006V were stopped from 95 mph, the other were stopped from 100 mph
NA Not Applicable
NR Test Not Run
FWD Front Wheel Drive
RWD Rear Wheel Drive

Table 8

STOPPING DISTANCES IN FMVSS 105

TEST PORTION	SPEED	LOADING	REQUIREMENT	O. E. TIRE	'SPORTY' TIRE
First Eff	30 mph	GVW	57 feet	49.0	43.2
	60 mph	GVW	216 feet	197.0	167.7
Second Eff	30 mph	GVW	54 feet	45.8	44.1
	60 mph	GVW	204 feet	190.6	173.1
	80 mph	GVW	383 feet	365.8	316.7
Third Eff	60 mph	LLV	194 feet	162.0	140.0
Partials	60 mph	LLV	456 feet	344.1 365.8	296.1 292.4
		GVW	456 feet	418.4 442.0	358.1 352.6
Failed Boost	60mph	GVW	456 feet	340.0	283.6
Fourth Eff	30 mph	GVW	57 feet	46.5	44.8
	60 mph	GVW	216 feet	193.9	167.0
	80 mph	GVW	405 feet	353.2	311.3
	100 mph	GVW	673 feet	554.7	498.7

Table 9

GM DATA REPORTS FOR THE PROPOSED FMVSS 135 TESTS

TEST NUMBER: 003V
DATE COMPL: 08/08/85
VEH: 85 RWD
80% Vmax: 146 km/h

TEST NAME	REQ. (ft)	PERF. (ft)	%PASS (-FAIL)	APPLY FORCE
PRE-BURNISH EFF.	236	208	11.9 %	55
1ST COLD EFF.	214	190	11.2 %	100
2ND COLD EFF.	214	NR	NR	NR
ADHESION UTIL.	*	NR	NR	NR
HIGH SPEED EFF.	**	440	12.1 %	61
ENGINE OFF EFF.	236	199	15.7 %	103
LLVW COLD EFF.	214	184	14.0 %	80
LLVW HIGH SPEED EFF.	**	369	26.3 %	90
LLVW ENGINE OFF EFF.	236	NR	NR	NR
1/2 SYSTEM 1, LLVW	509	480	5.7 %	69
1/2 SYSTEM 2, LLVW	509	231	54.6 %	80
ANTILOCK	263	NA	NA	NA
H.S.P.V.	263	NA	NA	NA
1/2 SYSTEM 1, GVWR	509	593	-16.5 %	116
1/2 SYSTEM 2, GVWR	509	273	46.4 %	81
ANTILOCK	263	NA	NA	NA
H.S.P.V.	263	NA	NA	NA
NO POWER, SYSTEM 1	509	546	-7.3 %	114
NO POWER, SYSTEM 2	509	NR	NR	NR
HOT PERFORMANCE EFF.	298	363	-21.8 %	45
RECOVERY EFF.	**	299	-10.2 %	41
PARK UP	***	113 lb	YES	--
PARK DOWN	***	113 lb	YES	--
DYNAMIC PARK 60 km/h	238	231	2.9 %	113
SPIKES	NR	NR	NR	NR
FINAL COLD EFF.	236	224	5.1 %	92

* Requirements proscribed in proposed FMVSS 135
** Calculated by Formulas in proposed FMVSS 135
*** 113 lb for Pedal; 72 lb for Hand
WL Wheel Lockup
NA Not Applicable
NR Test Not Run
FWD Front Wheel Drive
RWD Rear Wheel Drive

Table 10

GM DATA REPORTS FOR THE PROPOSED FMVSS 135 TESTS

TEST NUMBER: 004V
DATE COMPL: 08/17/85
VEH: 85 FWD
80% Vmax: 134 km/h

TEST NAME	REQ. (ft)	PERF. (ft)	%PASS (-FAIL)	APPLY FORCE
PRE-BURNISH EFF.	236	239	-1.3 %	55
1ST COLD EFF.	214	208	2.8 %	50
2ND COLD EFF.	214	NR	NR	NR
ADHESION UTIL.	*	NR	NR	NR
HIGH SPEED EFF.	**	404	4.6 %	56
ENGINE OFF EFF.	236	213	9.7 %	70
LLVW COLD EFF.	214	212	0.9 %	37
LLVW HIGH SPEED EFF.	**	346	18.3 %	50
LLVW ENGINE OFF EFF.	236	NR	NR	NR
1/2 SYSTEM 1, LLVW	509	351	31.0 %	70
1/2 SYSTEM 2, LLVW	509	375	26.3 %	85
ANTILOCK	263	NA	NA	NA
H.S.P.V.	263	NA	NA	NA
1/2 SYSTEM 1, GVWR	509	453	11.0 %	62
1/2 SYSTEM 2, GVWR	509	491	3.5 %	58
ANTILOCK	263	NA	NA	NA
H.S.P.V.	263	NA	NA	NA
NO POWER, SYSTEM 1	509	484	4.9 %	110
NO POWER, SYSTEM 2	509	NR	NR	NR
HOT PERFORMANCE EFF.	298	NR	NR	NR
RECOVERY EFF.	**	229	22.9 %	50
PARK UP	***	114 lb	NO	--
PARK DOWN	***	108 lb	YES	--
DYNAMIC PARK 60 km/h	238	187	21.4 %	90
SPIKES	NR	NR	NR	NR
FINAL COLD EFF.	236	208	11.9 %	76

* Requirements proscribed in proposed FMVSS 135
** Calculated by Formulas in proposed FMVSS 135
*** 113 lb for Pedal; 72 lb for Hand
WL Wheel Lockup
NA Not Applicable
NR Test Not Run
FWD Front Wheel Drive
RWD Rear Wheel Drive

Table 11

GM DATA REPORTS FOR THE PROPOSED FMVSS 135 TESTS

TEST NUMBER: 007V
DATE COMPL: 08/21/85
VEH: 85 RWD
80% Vmax: 146 km/h

TEST NAME	REQ. (ft)	PERF. (ft)	%PASS (-FAIL)	APPLY FORCE
PRE-BURNISH EFF.	236	214	9.3 %	53
1ST COLD EFF.	214	192	10.3 %	71
2ND COLD EFF.	214	198	7.5 %	82
ADHESION UTIL.	*	NR	NR	NR
HIGH SPEED EFF.	**	418	16.5 %	91
ENGINE OFF EFF.	236	191	19.1 %	140
LLVW COLD EFF.	214	195	8.9 %	95
LLVW HIGH SPEED EFF.	**	388	22.5 %	83
LLVW ENGINE OFF EFF.	236	NR	NR	NR
1/2 SYSTEM 1, LLVW	509	494	2.9 %	85
1/2 SYSTEM 2, LLVW	509	231	54.6 %	102
ANTILOCK	263	NA	NA	NA
H.S.P.V.	263	NA	NA	NA
1/2 SYSTEM 1, GVWR	509	515	-1.2 %	114
1/2 SYSTEM 2, GVWR	509	267	47.5 %	89
ANTILOCK	263	NA	NA	NA
H.S.P.V.	263	NA	NA	NA
NO POWER, SYSTEM 1	509	519	-2.0 %	125
NO POWER, SYSTEM 2	509	NR	NR	NR
HOT PERFORMANCE EFF.	298	WL	NA	40
RECOVERY EFF.	**	WL	NA	40
PARK UP	***	113 lb	YES	--
PARK DOWN	***	110 lb	YES	--
DYNAMIC PARK 60 km/h	238	275	-15.5 %	112
SPIKES	NR	NR	NR	NR
FINAL COLD EFF.	236	217	8.1 %	84

* Requirements proscribed in proposed FMVSS 135
** Calculated by Formulas in proposed FMVSS 135
*** 113 lb for Pedal; 72 lb for Hand
WL Wheel Lockup
NA Not Applicable
NR Test Not Run
FWD Front Wheel Drive
RWD Rear Wheel Drive

Table 12

GM DATA REPORTS FOR THE PROPOSED FMVSS 135 TESTS

TEST NUMBER: 008V
DATE COMPL: 08/17/85
VEH: 85 FWD
80% Vmax: 134 km/h

TEST NAME	REQ. (ft)	PERF. (ft)	%PASS (-FAIL)	APPLY FORCE
PRE-BURNISH EFF.	236	220	6.8 %	100
1ST COLD EFF.	214	224	-4.7 %	70
2ND COLD EFF.	214	218	-1.9 %	56
ADHESION UTIL.	*	NR	NR	NR
HIGH SPEED EFF.	**	383	9.5 %	105
ENGINE OFF EFF.	236	210	11.0 %	62
LLVW COLD EFF.	214	210	1.9 %	55
LLVW HIGH SPEED EFF.	**	333	21.3 %	60
LLVW ENGINE OFF EFF.	236	NR	NR	NR
1/2 SYSTEM 1, LLVW	509	357	29.9 %	65
1/2 SYSTEM 2, LLVW	509	377	25.9 %	60
ANTILOCK	263	NA	NA	NA
H.S.P.V.	263	NA	NA	NA
1/2 SYSTEM 1, GVWR	509	429	15.7 %	85
1/2 SYSTEM 2, GVWR	509	494	2.9 %	85
ANTILOCK	263	NA	NA	NA
H.S.P.V.	263	NA	NA	NA
NO POWER, SYSTEM 1	509	461	9.4 %	105
NO POWER, SYSTEM 2	509	NR	NR	NR
HOT PERFORMANCE EFF.	298	317	-6.4 %	56
RECOVERY EFF.	**	223	30.3 %	56
PARK UP	***	113 lb	YES	--
PARK DOWN	***	110 lb	YES	--
DYNAMIC PARK 60 km/h	238	258	-8.4 %	85
SPIKES	NR	NR	NR	NR
FINAL COLD EFF.	236	220	6.8 %	109

* Requirements proscribed in proposed FMVSS 135
** Calculated by Formulas in proposed FMVSS 135
*** 113 lb for Pedal; 72 lb for Hand
WL Wheel Lockup
NA Not Applicable
NR Test Not Run
FWD Front Wheel Drive
RWD Rear Wheel Drive

Table 13

GM DATA REPORTS FOR THE PROPOSED FMVSS 135 TESTS

TEST NUMBER: 011V
DATE COMPL: 10/25/85
VEH: 85 FWD JA2
80% Vmax: 134 km/h

TEST NAME	REQ. (ft)	PERF. (ft)	%PASS (-FAIL)	APPLY FORCE
PRE-BURNISH EFF.	236	224.1	5.0 %	80
1ST COLD EFF.	214	216.8	-1.3 %	50
2ND COLD EFF.	214	223.6	-4.5 %	65
ADHESION UTIL.	*	NR	NR	NR
HIGH SPEED EFF.	**	409.4	3.3 %	59
ENGINE OFF EFF.	236	211.2	10.5 %	70
LLVW COLD EFF.	214	168.5	21.3 %	50
LLVW HIGH SPEED EFF.	**	338.6	20.0 %	50
LLVW ENGINE OFF EFF.	236	NR	NR	NR
1/2 SYSTEM 1, LLVW	509	368.2	27.7 %	40
1/2 SYSTEM 2, LLVW	509	400.7	21.3 %	48
ANTILOCK	263	NA	NA	NA
H.S.P.V.	263	NA	NA	NA
1/2 SYSTEM 1, GVWR	509	449.9	11.6 %	37
1/2 SYSTEM 2, GVWR	509	500.5	1.7 %	60
ANTILOCK	263	NA	NA	NA
H.S.P.V.	263	NA	NA	NA
NO POWER, SYSTEM 1	509	491.0	3.5 %	112
NO POWER, SYSTEM 2	509	NR	NR	NR
HOT PERFORMANCE EFF.	298	NA	NA	NA
RECOVERY EFF.	**	320.6	-3.5 %	33
PARK UP	***	NR	NR	NR
PARK DOWN	***	NR	NR	NR
DYNAMIC PARK 60 km/h	238	214.5	9.9 %	100
SPIKES	NR	NR	NR	NR
FINAL COLD EFF.	236	218.9	7.2 %	92

* Requirements proscribed in proposed FMVSS 135
** Calculated by Formulas in proposed FMVSS 135
*** 113 lb for Pedal; 72 lb for Hand
WL Wheel Lockup
NA Not Applicable
NR Test Not Run
FWD Front Wheel Drive
RWD Rear Wheel Drive

Table 14

GM DATA REPORTS FOR THE PROPOSED FMVSS 135 TESTS

TEST NUMBER: 012
DATE COMPL: 10/02/85
VEH: 85 FWD JA2
80% Vmax: 134 km/h

TEST NAME	REQ. (ft)	PERF. (ft)	%PASS (-FAIL)	APPLY FORCE
PRE-BURNISH EFF.	236	197.4	16.4 %	125
1ST COLD EFF.	214	193.8	9.4 %	82
2ND COLD EFF.	214	179.1	16.3 %	85
ADHESION UTIL.	*	NR	NR	NR
HIGH SPEED EFF.	**	341.2	19.4 %	90
ENGINE OFF EFF.	236	209.1	11.4 %	78
LLVW COLD EFF.	214	163.6	23.6 %	84
LLVW HIGH SPEED EFF.	**	267.7	36.8 %	70
LLVW ENGINE OFF EFF.	236	NR	NR	NR
1/2 SYSTEM 1, LLVW	509	341.6	32.9 %	48
1/2 SYSTEM 2, LLVW	509	352.0	30.8 %	70
ANTILOCK	263	NA	NA	NA
H.S.P.V.	263	NA	NA	NA
1/2 SYSTEM 1, GVWR	509	375.8	26.2 %	76
1/2 SYSTEM 2, GVWR	509	378.3	25.7 %	90
ANTILOCK	263	NA	NA	NA
H.S.P.V.	263	NA	NA	NA
NO POWER, SYSTEM 1	509	438.0	13.9 %	112
NO POWER, SYSTEM 2	509	NR	NR	NR
HOT PERFORMANCE EFF.	298	299.7	-0.6	35
RECOVERY EFF.	**	278.3	-0.5	35
PARK UP	***	111 lb	NO	--
PARK DOWN	***	112 lb	YES	--
DYNAMIC PARK 60 km/h	238	191.8	19.4 %	97
SPIKES	NR	NR	NR	NR
FINAL COLD EFF.	236	205.3	13.0 %	109

* Requirements proscribed in proposed FMVSS 135
** Calculated by Formulas in proposed FMVSS 135
*** 113 lb for Pedal; 72 lb for Hand
WL Wheel Lockup
NA Not Applicable
NR Test Not Run
FWD Front Wheel Drive
RWD Rear Wheel Drive

Table 15

GM DATA REPORTS FOR THE PROPOSED FMVSS 135 TESTS		TEST NUMBER: 013V DATE COMPL: 11/14/85 VEH: 85 FWD (4 DISK) 80% Vmax: 137 km/h		
TEST NAME	REQ. (ft)	PERF. (ft)	%PASS (-FAIL)	APPLY FORCE
PRE-BURNISH EFF.	236	211.3	10.5 %	82
1ST COLD EFF.	214	199.3	6.9 %	115
2ND COLD EFF.	214	181.2	15.3 %	109
ADHESION UTIL.	*	NR	NR	NR
HIGH SPEED EFF.	**	335.8	24.0 %	69
ENGINE OFF EFF.	236	187.3	20.6 %	70
LLVW COLD EFF.	214	164.3	23.2 %	66
LLVW HIGH SPEED EFF.	**	321.1	27.4 %	49
LLVW ENGINE OFF EFF.	236	NR	NR	NR
1/2 SYSTEM 1, LLVW	509	308.6	39.4 %	60
1/2 SYSTEM 2, LLVW	509	324.4	36.3 %	45
ANTILOCK	263	NA	NA	NA
H.S.P.V.	263	NA	NA	NA
1/2 SYSTEM 1, GVWR	509	373.7	26.6 %	47
1/2 SYSTEM 2, GVWR	509	360.5	29.2 %	52
ANTILOCK	263	NA	NA	NA
H.S.P.V.	263	NA	NA	NA
NO POWER, SYSTEM 1	509	436.4	14.3 %	106
NO POWER, SYSTEM 2	509	NR	NR	NR
HOT PERFORMANCE EFF.	298	319.9	-7.3	34
RECOVERY EFF.	**	285.7	-0.3	30
PARK UP	***	112 lb	YES	--
PARK DOWN	***	112 lb	YES	--
DYNAMIC PARK 60 km/h	238	187.2	21.3 %	95
SPIKES	NR	NR	NR	NR
FINAL COLD EFF.	236	168.2	28.7 %	94

* Requirements proscribed in proposed FMVSS 135
** Calculated by Formulas in proposed FMVSS 135
*** 113 lb for Pedal; 72 lb for Hand
WL Wheel Lockup
NA Not Applicable
NR Test Not Run
FWD Front Wheel Drive
RWD Rear Wheel Drive

Table 16

GM DATA REPORTS FOR THE PROPOSED FMVSS 135 TESTS

TEST NUMBER: 398T
DATE COMPL: 09/08/85
VEH: 85 FWD MANUAL
80% Vmax: 115.8 km/h

TEST NAME	REQ. (ft)	PERF. (ft)	%PASS (-FAIL)	APPLY FORCE
PRE-BURNISH EFF.	236	263	-11.4 %	112
1ST COLD EFF.	214	255	-19.2 %	112
2ND COLD EFF.	214	259	-21.0 %	112
ADHESION UTIL.	*	NR	NR	NR
HIGH SPEED EFF.	**	345	18.5 %	108
ENGINE OFF EFF.	236	NR	NR	NR
LLVW COLD EFF.	214	237	-10.7 %	115
LLVW HIGH SPEED EFF.	**	NR	NR	NR
LLVW ENGINE OFF EFF.	236	NR	NR	NR
1/2 SYSTEM 1, LLVW	509	307	39.7 %	112
1/2 SYSTEM 2, LLVW	509	791	-55.4 %	112
ANTILOCK	263	NA	NA	NA
H.S.P.V.	263	NA	NA	NA
1/2 SYSTEM 1, GVWR	509	291	42.8 %	110
1/2 SYSTEM 2, GVWR	509	797	-56.6 %	110
ANTILOCK	263	NA	NA	NA
H.S.P.V.	263	NA	NA	NA
NO POWER, SYSTEM 1	509	NA	NA	NA
NO POWER, SYSTEM 2	509	NA	NA	NA
HOT PERFORMANCE EFF.	298	314	-5.4 %	115
RECOVERY EFF.	**	278	23.7 %	114
PARK UP	***	52 lb	YES	--
PARK DOWN	***	50 lb	YES	--
DYNAMIC PARK 60 km/h	238	140	41.2 %	58
SPIKES	NR	NR	NR	NR
FINAL COLD EFF.	236	256	-8.5 %	112

* Requirements proscribed in proposed FMVSS 135
** Calculated by Formulas in proposed FMVSS 135
*** 113 lb for Pedal; 72 lb for Hand
WL Wheel Lockup
NA Not Applicable
NR Test Not Run
FWD Front Wheel Drive
RWD Rear Wheel Drive

Table 17

GM DATA REPORTS FOR THE PROPOSED FMVSS 135 TESTS

TEST NUMBER: ABS
DATE COMPL: 11/08/85
VEH: 86 RWD HIGH PERF
80% Vmax: 193 km/h

TEST NAME	REQ. (ft)	PERF. (ft)	%PASS (-FAIL)	APPLY FORCE
PRE-BURNISH EFF.	236	169.0	28.4 %	50
1ST COLD EFF.	214	159.4	25.5 %	50
2ND COLD EFF.	214	148.6	30.6 %	50
ADHESION UTIL.	*	NR	NR	NR
HIGH SPEED EFF.	**	603.0	30.2 %	50
ENGINE OFF EFF.	236	145.0	38.6 %	50
LLVW COLD EFF.	214	149.4	30.2 %	50
LLVW HIGH SPEED EFF.	**	509.0	41.1 %	50
LLVW ENGINE OFF EFF.	236	147.0	37.7 %	50
1/2 SYSTEM 1, LLVW	509	329.0	35.4 %	50
1/2 SYSTEM 2, LLVW	509	211.0	58.5 %	50
ANTILOCK	263	158.0	39.9 %	45
H.S.P.V.	263	NA	NA	NA
1/2 SYSTEM 1, GVWR	509	322.0	36.7 %	50
1/2 SYSTEM 2, GVWR	509	215.0	57.8 %	50
ANTILOCK	263	153.5	41.6 %	45
H.S.P.V.	263	NA	NA	NA
NO POWER, SYSTEM 1	509	241.0	52.7 %	50
NO POWER, SYSTEM 2	509	NA	NA	NA
HOT PERFORMANCE EFF.	298	176.0	40.9 %	50
RECOVERY EFF.	**	164.3	27.8 %	50
PARK UP	***	NR	NR	NR
PARK DOWN	***	NR	NR	NR
DYNAMIC PARK 60 km/h	238	NR	NR	NR
SPIKES	NR	NR	NR	NR
FINAL COLD EFF.	236	146.7	37.8 %	50

* Requirements proscribed in proposed FMVSS 135
** Calculated by Formulas in proposed FMVSS 135
*** 113 lb for Pedal; 72 lb for Hand
WL Wheel Lockup
NA Not Applicable
NR Test Not Run
FWD Front Wheel Drive
RWD Rear Wheel Drive

FIG 1. 1985 RWD ON FMVSS 105

SEMI-MET/ASBESTOS

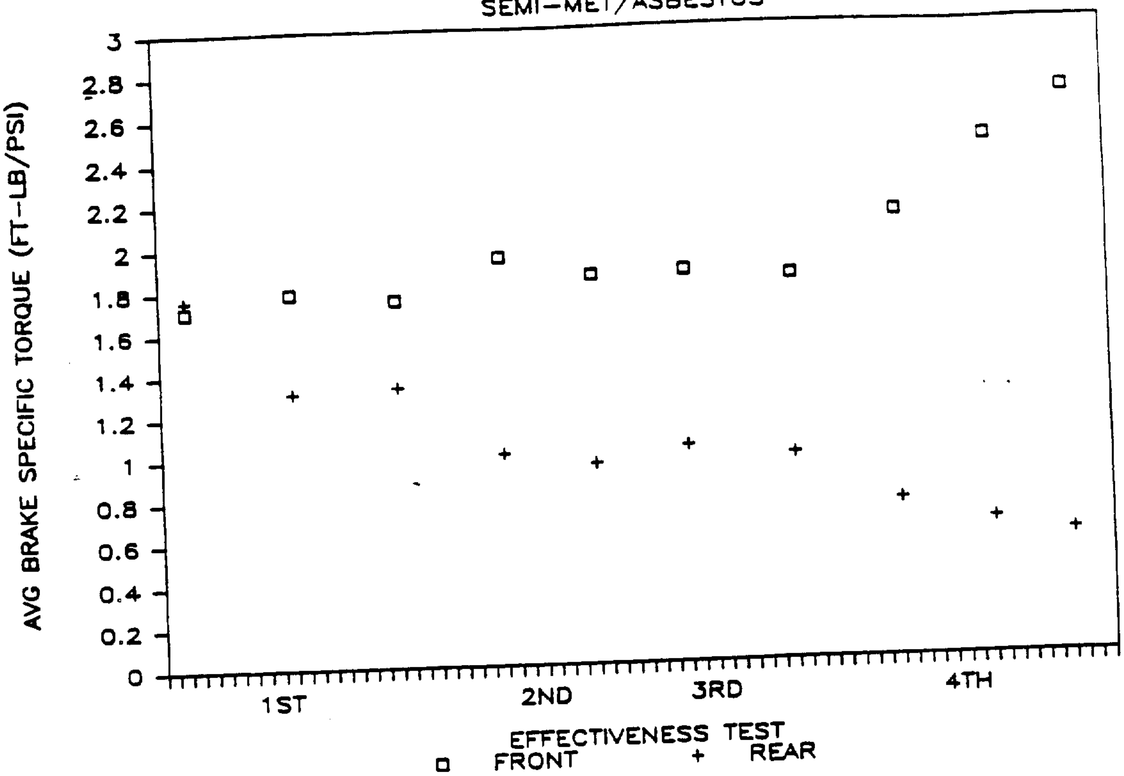


FIG 2. 1985 FWD ON FMVSS 105

SEMI-MET/ASBESTOS

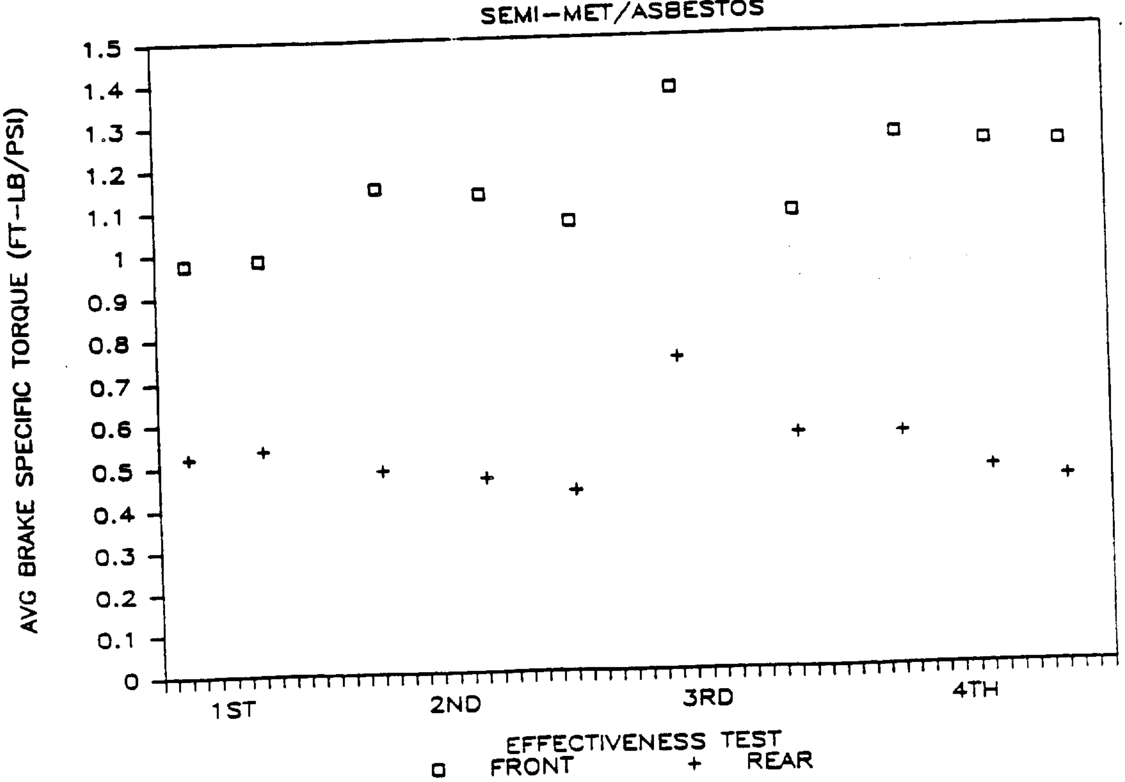


FIG 3. 1985 RWD ON FMVSS 135

SEMI-MET/ASBESTOS

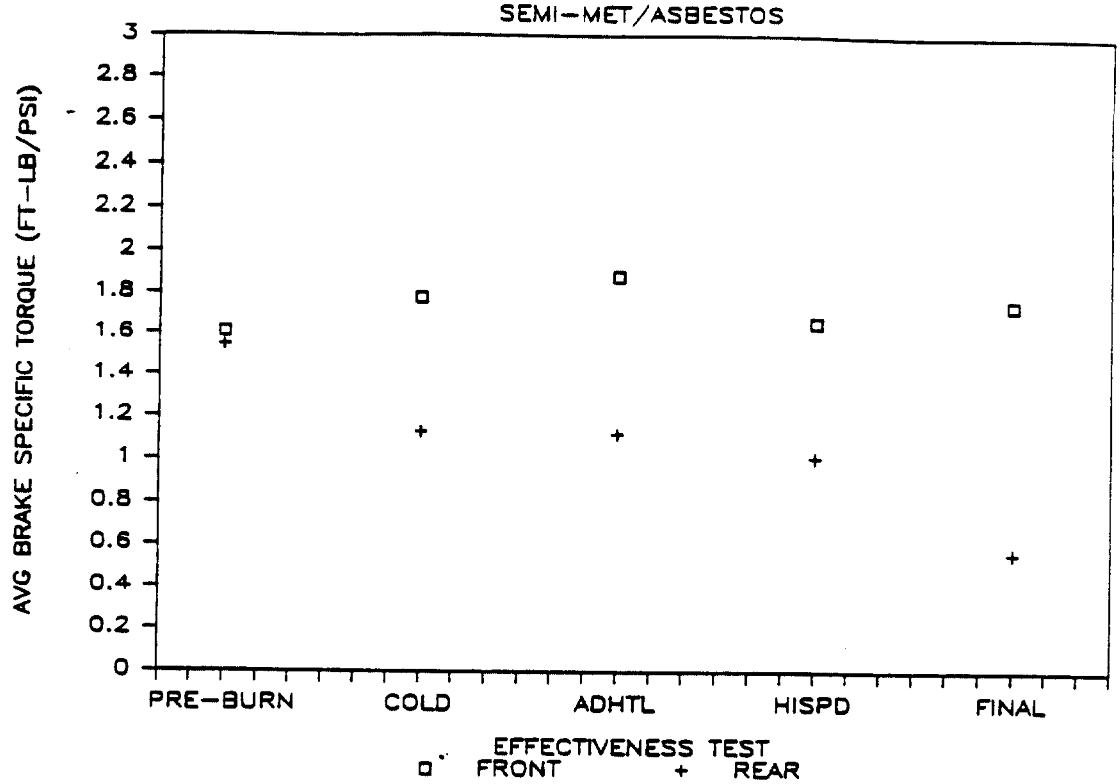


FIG 4. 1985 FWD ON FMVSS 135

SEMI-MET/ASBESTOS

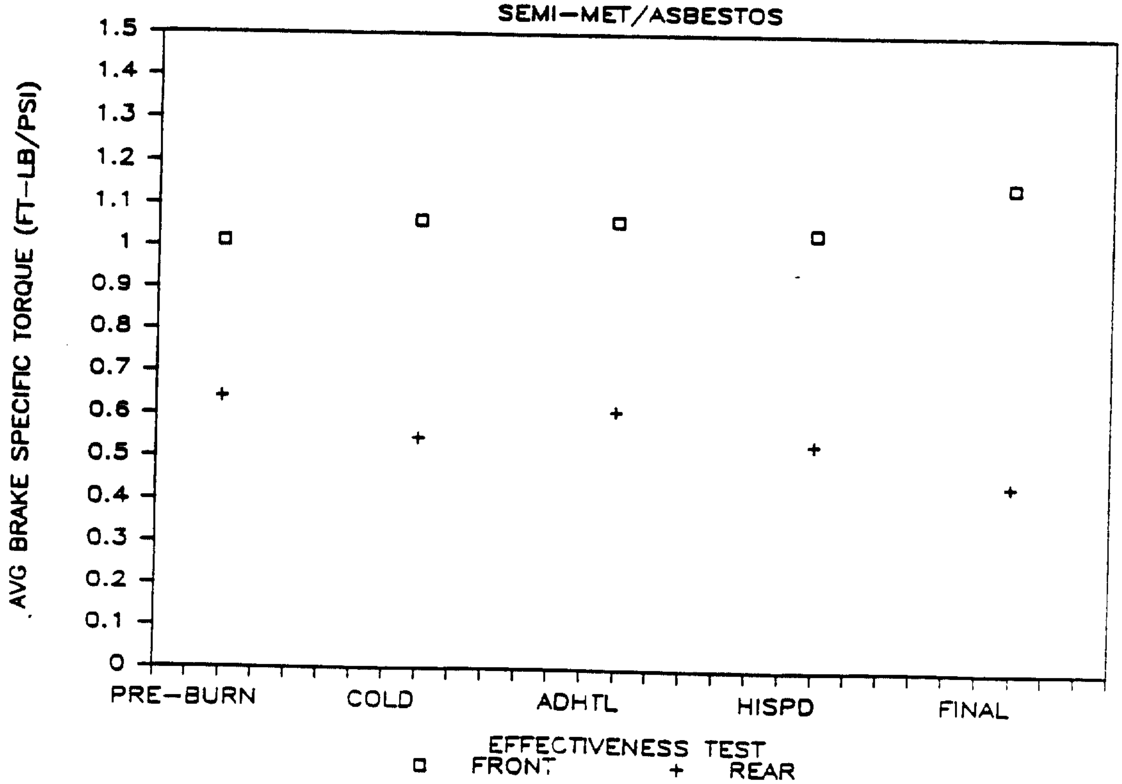


FIG 5. 1985 RWD ON FMVSS 105

ASBESTOS/ASBESTOS

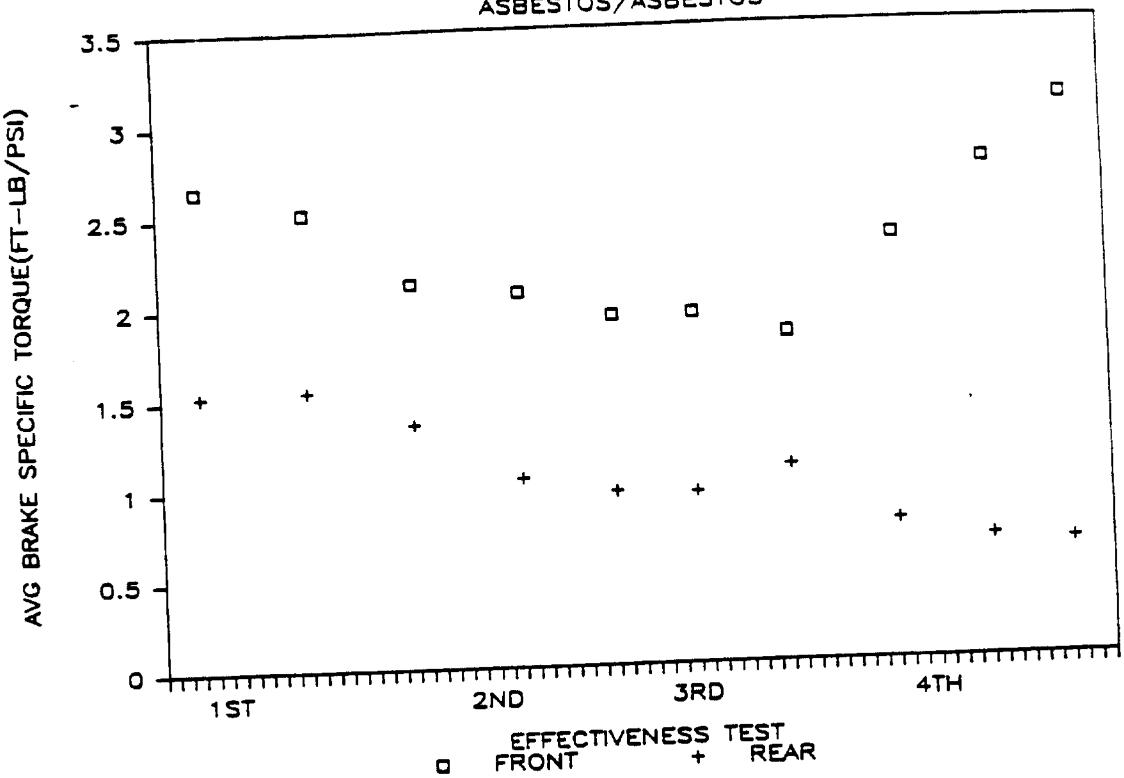


FIG 6. 1985 FWD ON FMVSS 105

SEMI-MET/ASBESTOS

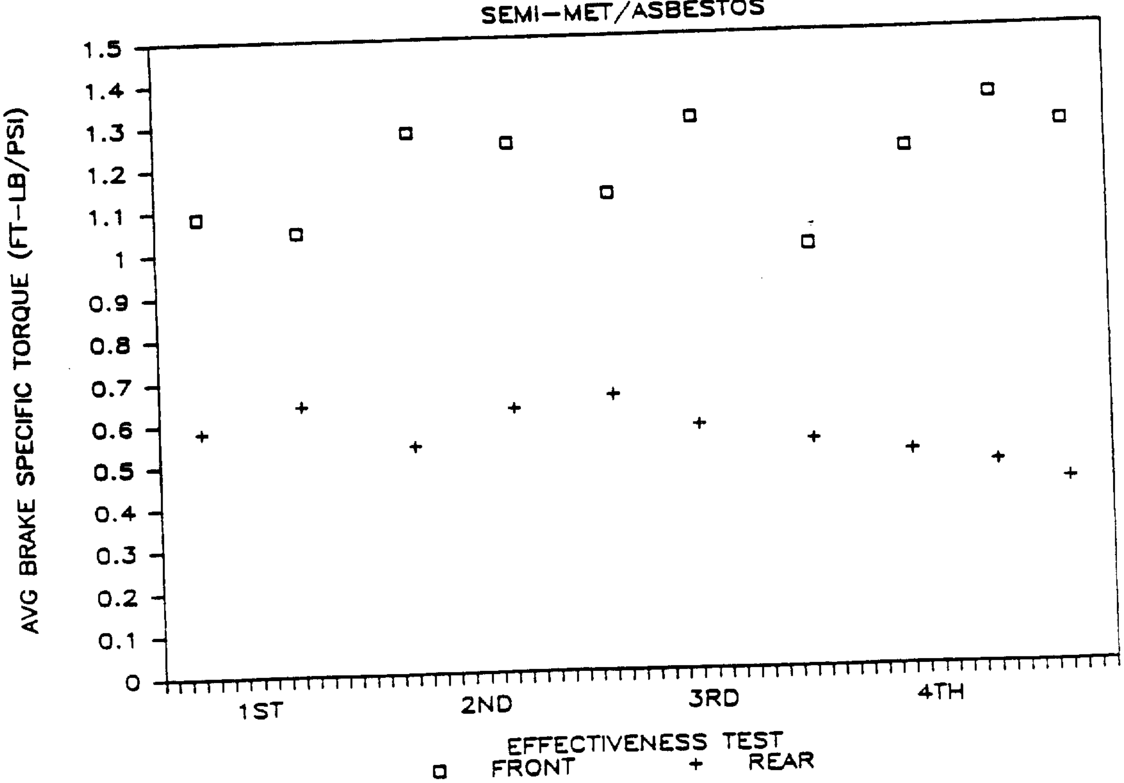


FIG 7. 1985 RWD ON FMVSS 135

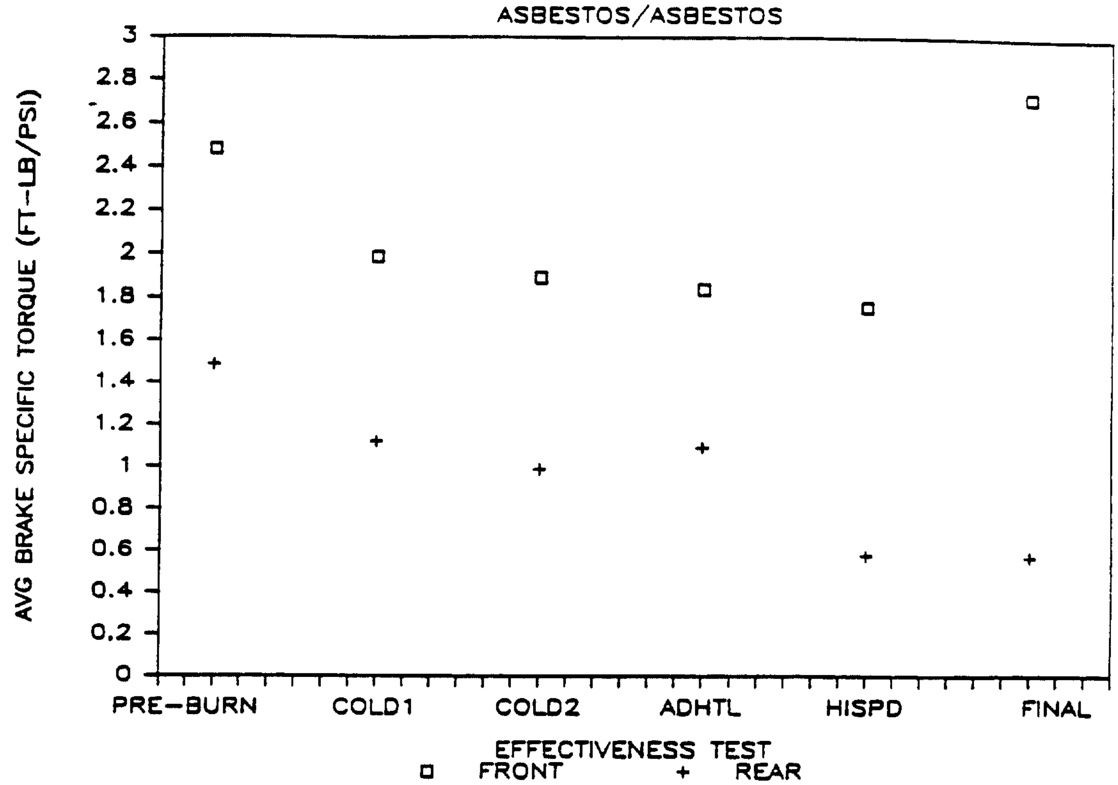


FIG 8. 1985 FWD ON FMVSS 135

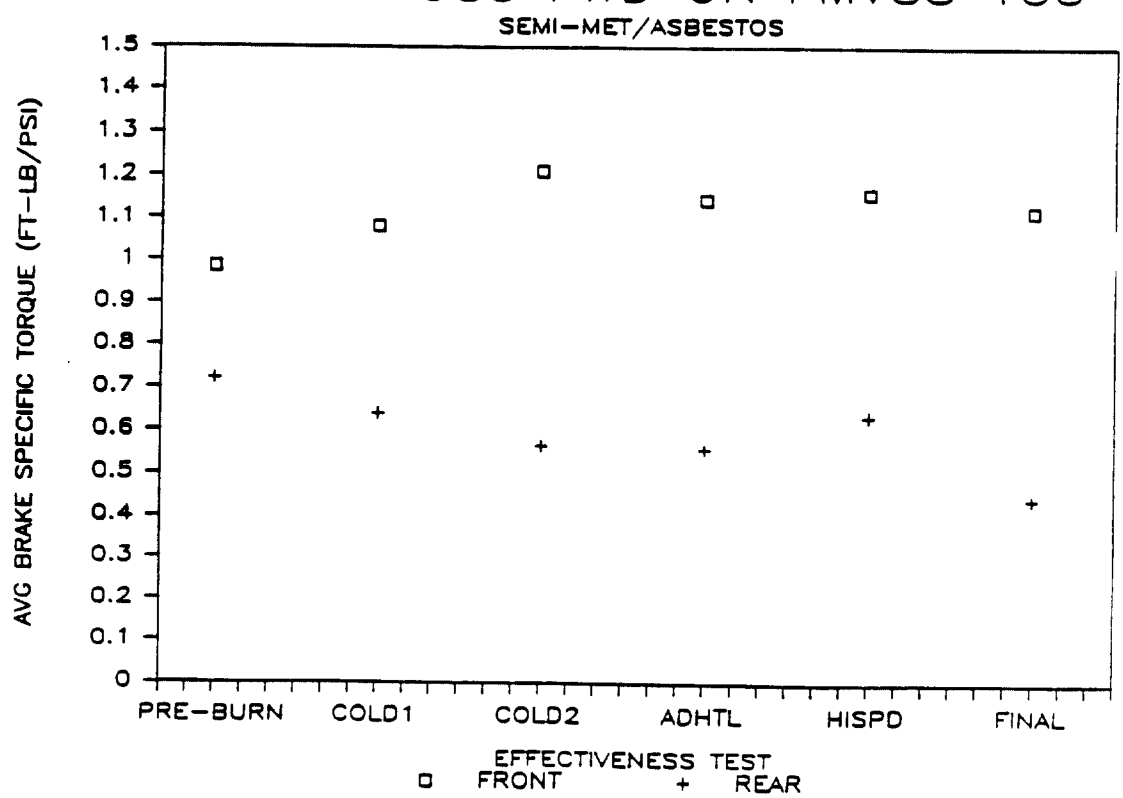


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FIG 9. 1985 FWD ON FMVSS 105

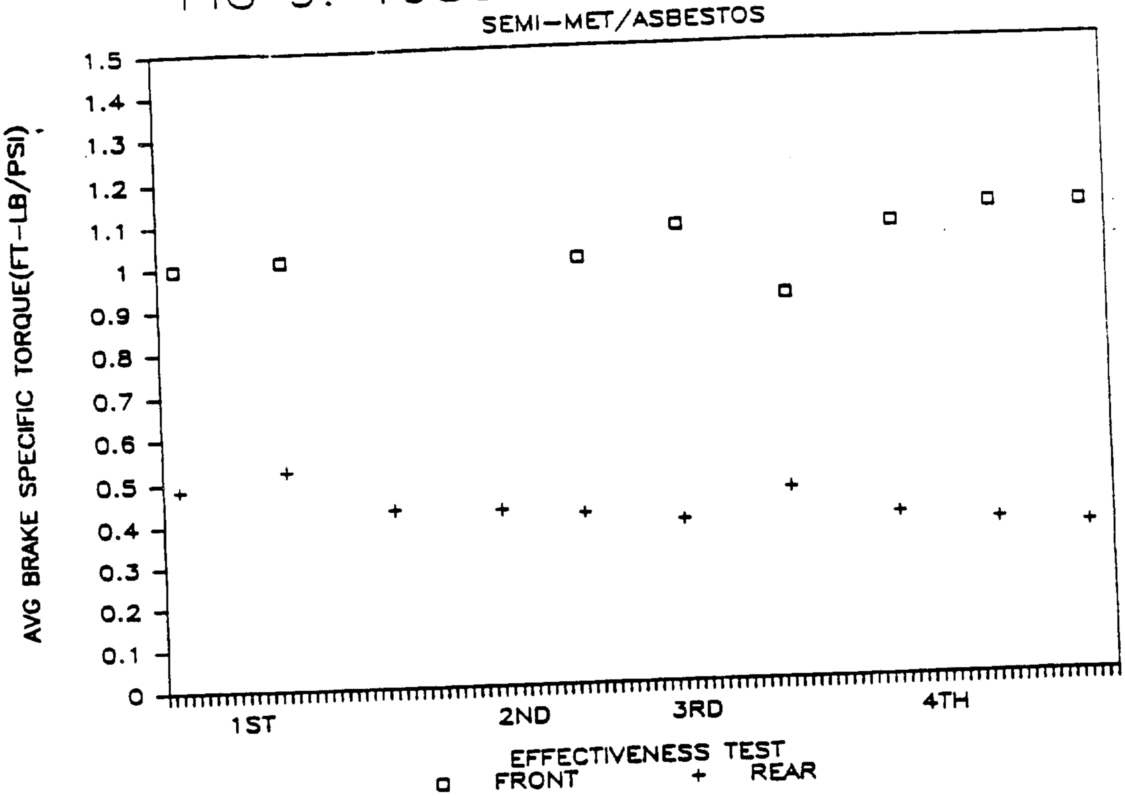


FIG 10. 1985 FOUR WHEEL DISC ON 105

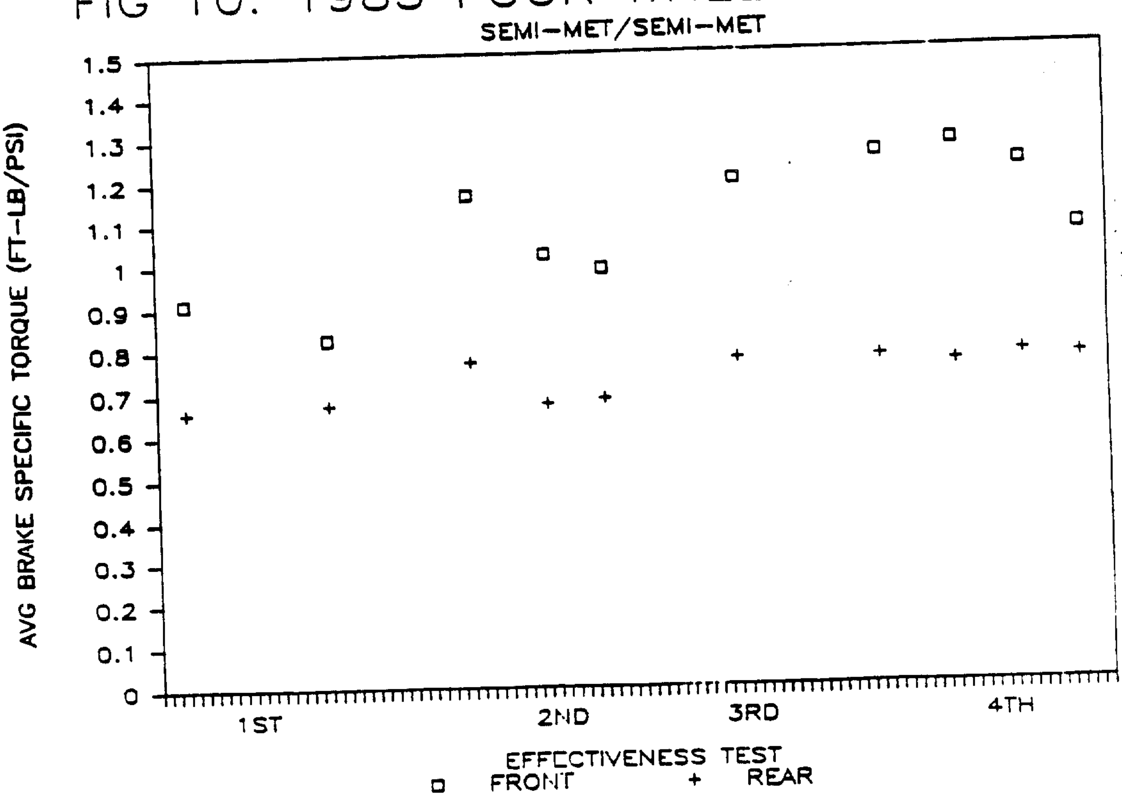


FIG 11.1985 FWD ON FMVSS 135

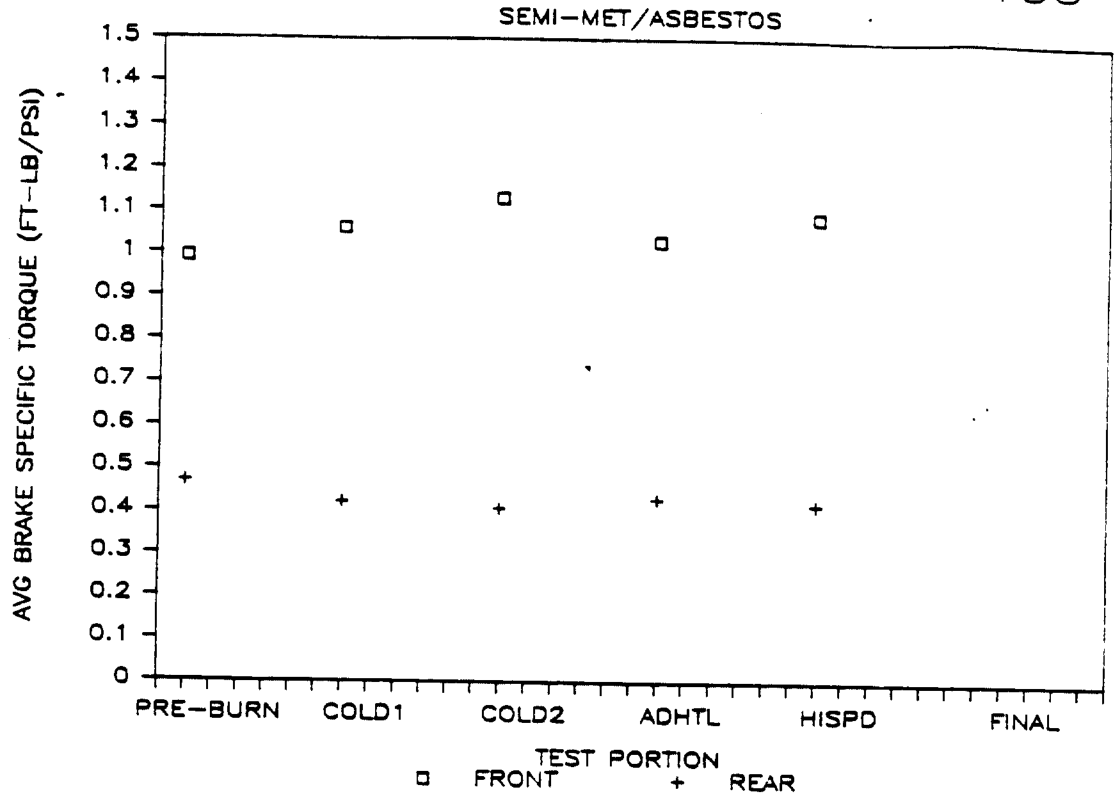
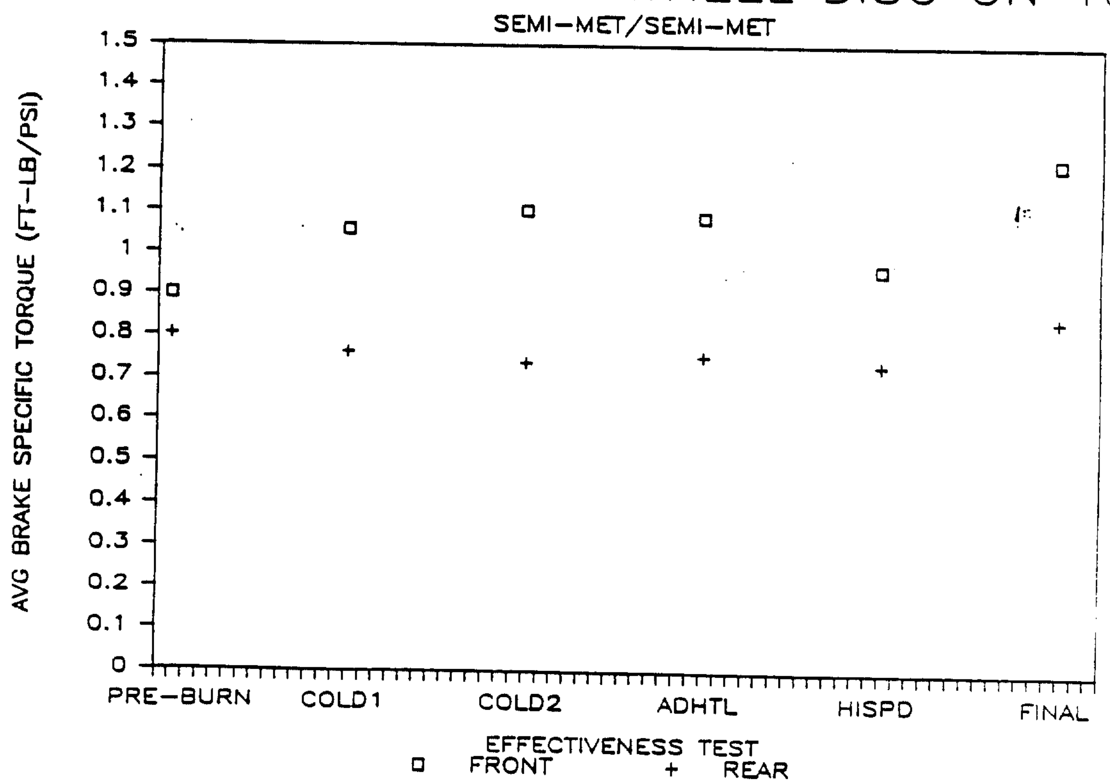


FIG 12.1985 FOUR WHEEL DISC ON 135



BRAKE SYSTEM REACTION TIME

OBJECTIVE

The purpose of this appendix is to establish a value for brake system reaction time to be used for all calculations in these comments and in revision of the FMVSS 135 proposal, based on actual test data with production systems. (Reaction time as used in this issue is strictly the time it takes a brake system to reach full output measured from the moment of application of pedal force. It is not a measurement of driver decision time.)

CONCLUSION

Brake system reaction times measured in laboratory tests of components used in vehicles meeting FMVSS 105 range as high as 0.8 second, with 0.6 seconds more typical. Full vehicle tests yielded a reaction time of 0.65 second.

RECOMMENDATIONS

1. NHTSA should use the ECE system reaction time factor of 0.1 for calculation of stopping distances. This corresponds to a reaction time of .72 seconds. The absolute minimum justifiable reaction time is 0.6 seconds which is equivalent to a reaction time factor of 0.0833 in the stopping distance formulas.

2. The stopping distance requirements of proposed FMVSS 135 should be increased to reflect a realistic system reaction time of .72 seconds.

DISCUSSION

NHTSA has chosen to adopt a smaller system reaction time constant for the stopping distance formula than allowed in ECE Regulation 13 or draft proposal R.88. Although discussions in various harmonization meetings have given us the impression that NHTSA has based the proposed reaction time on its test work, GM finds the conclusion the agency reached to be unsupported by our recent and historical test work, both laboratory and vehicle tests.

The general form of stopping distance equations is as follows:

$$SD = av + bv^2$$

where,

SD = stopping distance in meters

v = initial vehicle velocity in km/h

b = deceleration factor

a = brake system reaction time correction factor

The reaction time term is based on the assumption that the driver will require some finite time to apply the service brake (but not including the time he takes to determine a need to brake and get his foot to the pedal), and the braking system will likewise require some additional time to begin decelerating the vehicle. The time dependent behavior of vehicle deceleration is shown schematically in figure 1. Here, the vehicle deceleration is assumed to increase linearly with time from brake application to full deceleration in 0.36 seconds. This is then converted to an assumed equivalent step function increase in vehicle deceleration at 0.18 seconds. Thus, the allowed reaction time correction factor, a, is taken as 1/2 the full braking system reaction time. Converting km/h to m/s provides for a correction term value of

$$a = (1000/3600)(0.18) = 0.050$$

which is the value of the reaction time correction factor given in FMVSS 135 stopping distance formulas. The relevant question then is what reaction time is appropriate for vehicle tests where a skilled driver is attempting to produce the shortest possible stopping distance, and is this reaction time dependent upon vehicle velocity?

To address these fundamental questions, GM has reviewed several kinds of test data. The first group of test data is a series of laboratory evaluations of both hydraulic and vacuum booster response characteristics. In this series of tests, booster response as indicated by line pressure output was measured when various rates of brake force application were provided by a brake machine. Rates of 100 and 2000 pounds/sec (445 and 8896 N/sec) were applied to the vacuum booster studied. Plots of the normalized apply force and the normalized response are shown in figures 2 and 3. At either apply rate, the line pressure did not reach 95% of maximum output until about 0.60 seconds. For the hydraulic booster studied, apply rates of 500 and 2000 pounds/sec (2224 and 8896 N/sec) produced line pressure response to 95% of full value in times in excess of 0.80 seconds. The supporting data is shown in figures 4 and 5. While these laboratory tests with a brake apply machine are helpful in determining reaction time, they do not describe the behavior of complete brake systems operated by real drivers attempting to produce minimum stopping distances in certification tests.

To look at this more relevant issue, GM analyzed system reaction time data from vehicle tests conducted for this response. Fourth effectiveness stops in FMVSS 105 tests of both the FWD and RWD vehicle configurations were chosen for study. These particular stops were selected for this detailed analysis as both the system response and speed sensitivity questions could be evaluated. The results from the first stop of the highest speed tests were used to study brake system reaction time. For the FWD vehicle, the driver was required to apply a maximum of 35 pounds (155.7 N) to the pedal. Full vehicle deceleration, as calculated by summing the output of all four torque wheels and dividing by vehicle mass, was achieved in about 0.50 seconds. The RWD vehicle required 65 pounds (289.1 N) of pedal effort, and full vehicle deceleration was achieved in about 0.65 seconds. The normalized response curves for both these tests are shown in figures 6 and 7. These reaction times are measured from a trigger value of 3 pounds (13.3 N) of pedal force as measured with the digital data acquisition system used in the GM tests rather than a brake light switch as used in the NHTSA tests. GM experience is that brake light switch adjustment can vary substantially over a range of vehicles, and such a trigger was judged to be unreliable in determining the reaction time of the vehicle braking system.

It should be pointed out that these vehicle tests were performed by very skilled test drivers who run certification tests nearly daily. Typically, these drivers will make an impact apply to push right through the booster, and then quickly begin to modulate the brake pedal to avoid wheel lock as the booster begins to respond to the apply force. This driving technique is somewhat dependent upon the individual performing the test, and his familiarity with the particular vehicle system being tested.

The issue of system reaction time as a function of vehicle speed was raised in one of the international meetings regarding brake harmonization. GM reviewed data from FMVSS 105 4th effectiveness stops to examine this issue. Vehicle deceleration is plotted as a function of time at various speeds in the plots identified as figures 8 and 9. These curves fail to suggest that system reaction time is increased at higher vehicle speeds. These data suggest that drivers are able to achieve full vehicle deceleration, as calculated from the sum of the wheel torques, as quickly at high speeds as they are at low speeds.

Finally, the agency should realize that the test results cited here are for GM brake systems and components. The response time for any vehicle will be a function of many variables including pedal ratio, master cylinder size, booster size and design, and the inertia of all the hydraulic components downstream of the master cylinder. Depending upon how individual manufacturers choose to strike the compromises regarding boosters, master cylinders, and sizes of foundation brake components, different vehicles may produce different reaction times.

Based on the data summarized here, GM believes a system reaction time of 0.72 seconds, (a 1/2 period equivalent of 0.36 seconds), is a reasonable estimate of the broad range of manufacturers vehicles being built today. Using the 0.36 sec equivalent would provide a reaction time constant of 0.10 which is precisely the value given in ECE Regulation 13. In any case, an absolute minimum system reaction time of 0.60 seconds is justified, and this would provide a constant of 0.0833.

Based on this analysis we believe that the 0.05 constant used in the stopping distance equations of FMVSS 135 is much too small, and not representative of current brake system designs. Basing the proposed regulation on this low reaction time factor has led the agency to unrealistically short proposed stopping distances. Promulgation of a rule so based may preclude manufacturers from optimizing booster design, foundation brake design, and master cylinder configuration that are best for the consumer. The agency should carefully consider adopting the 0.10 reaction time multiplier currently used in ECE13.

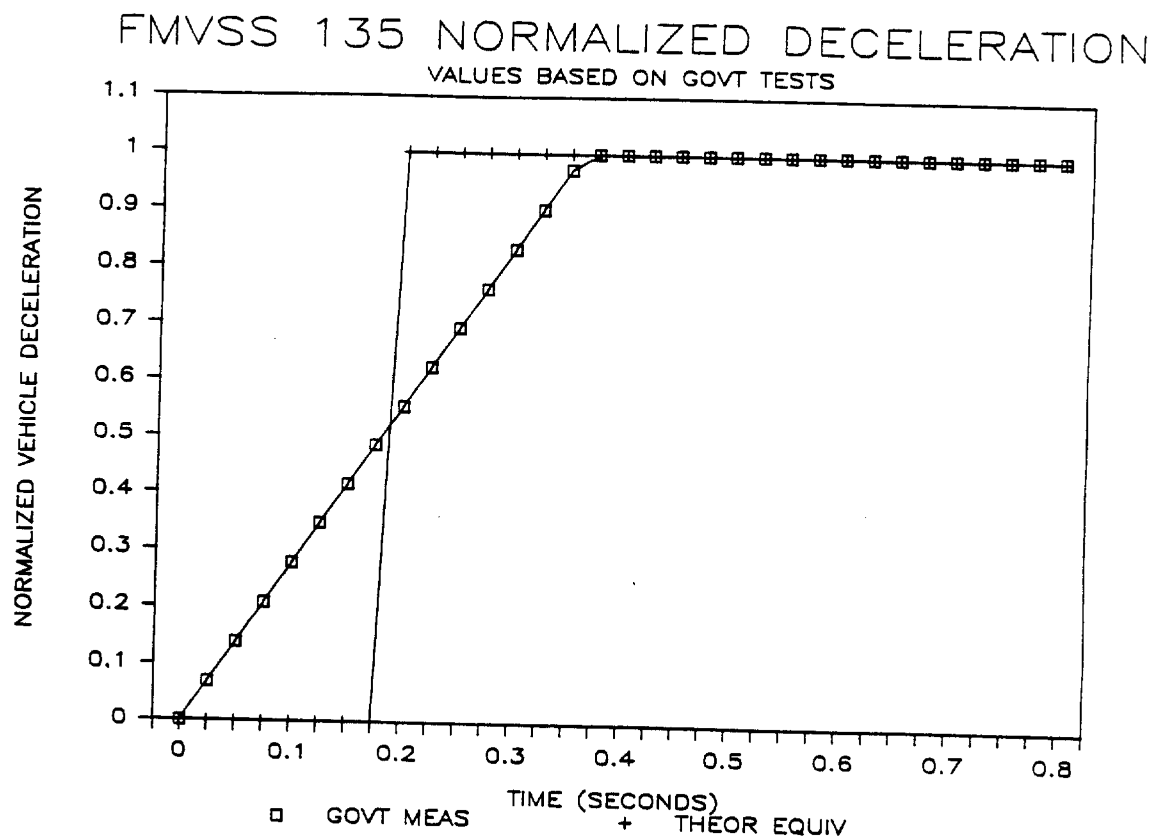


Figure 1

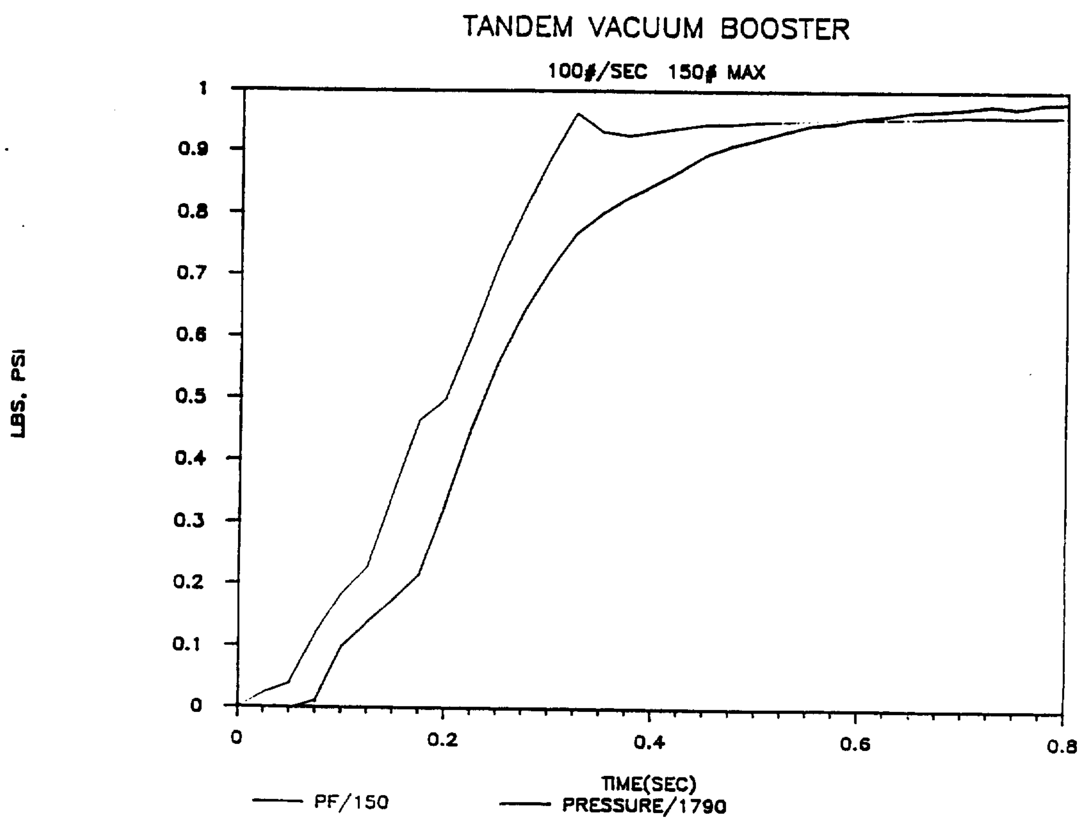


Figure 2

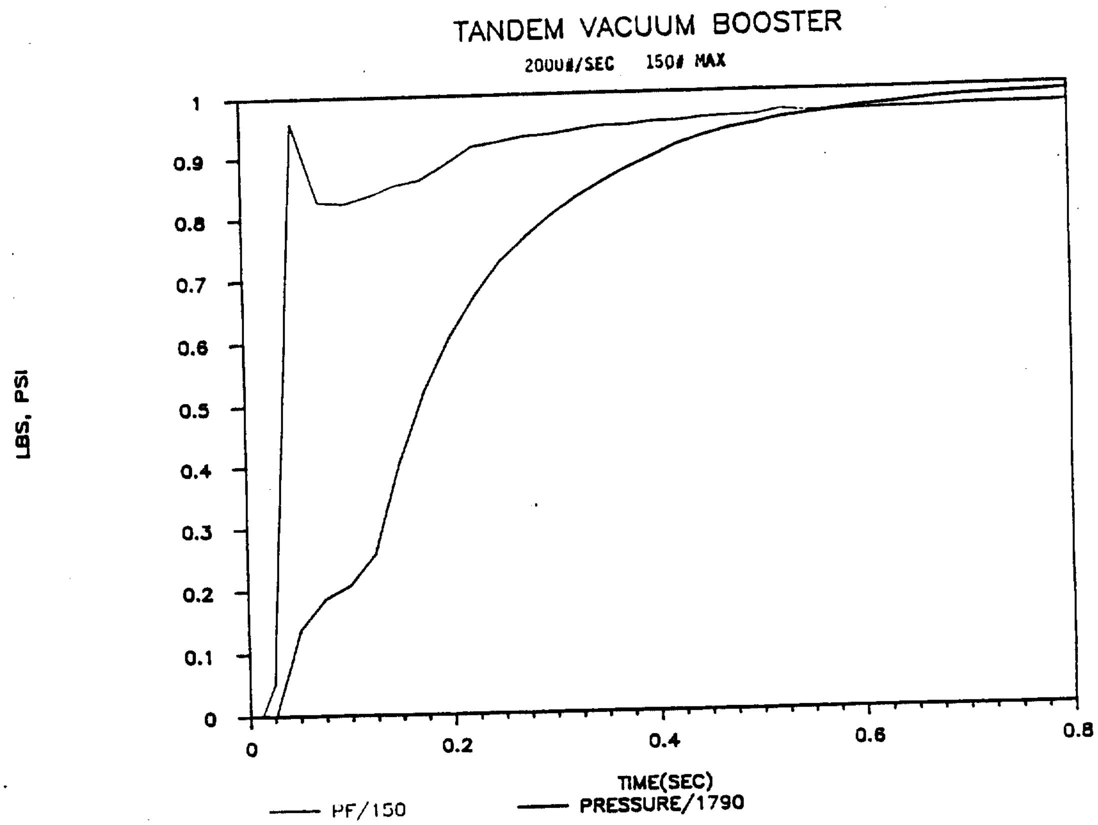


Figure 3

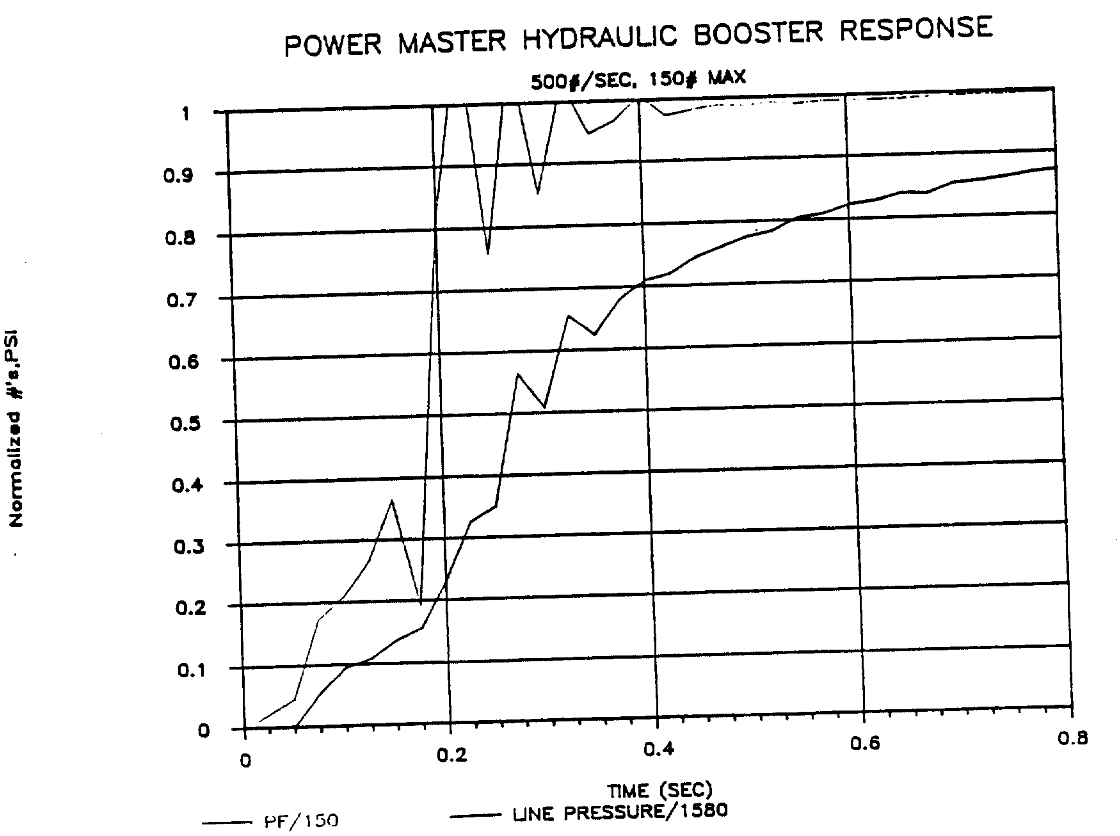


Figure 4

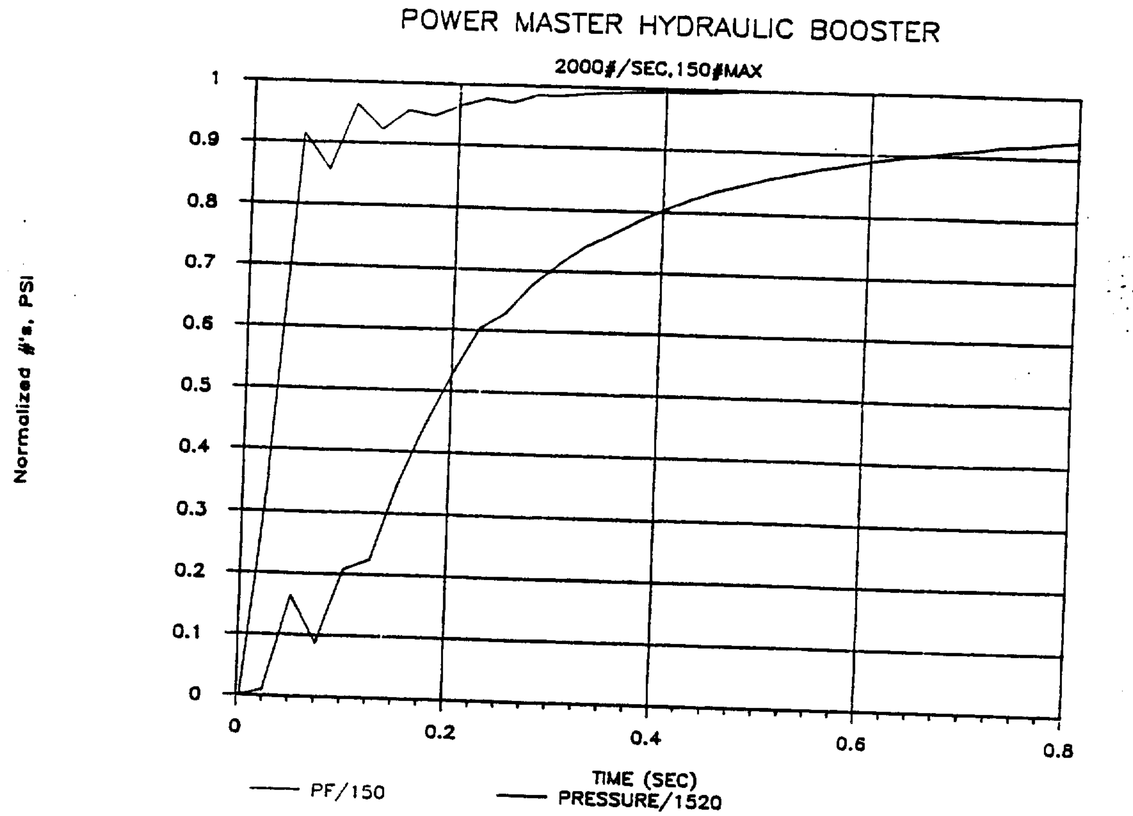


Figure 5

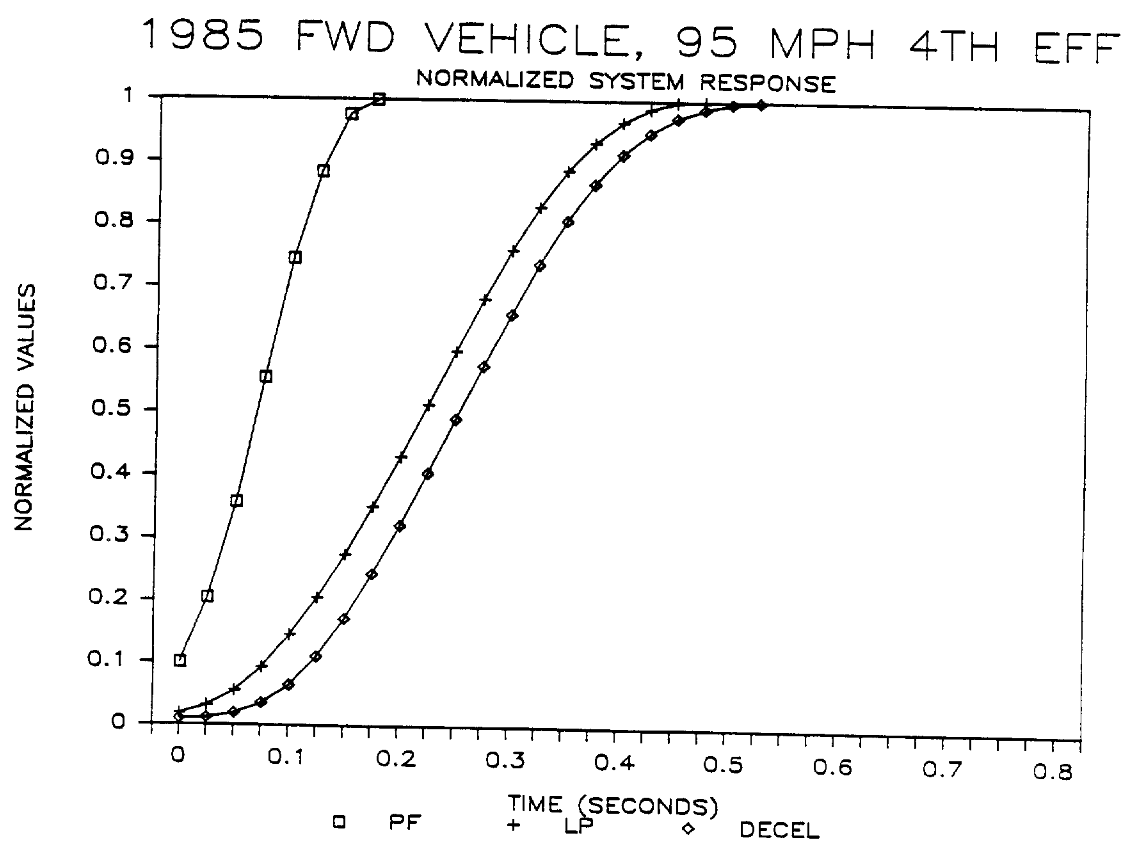


Figure 6

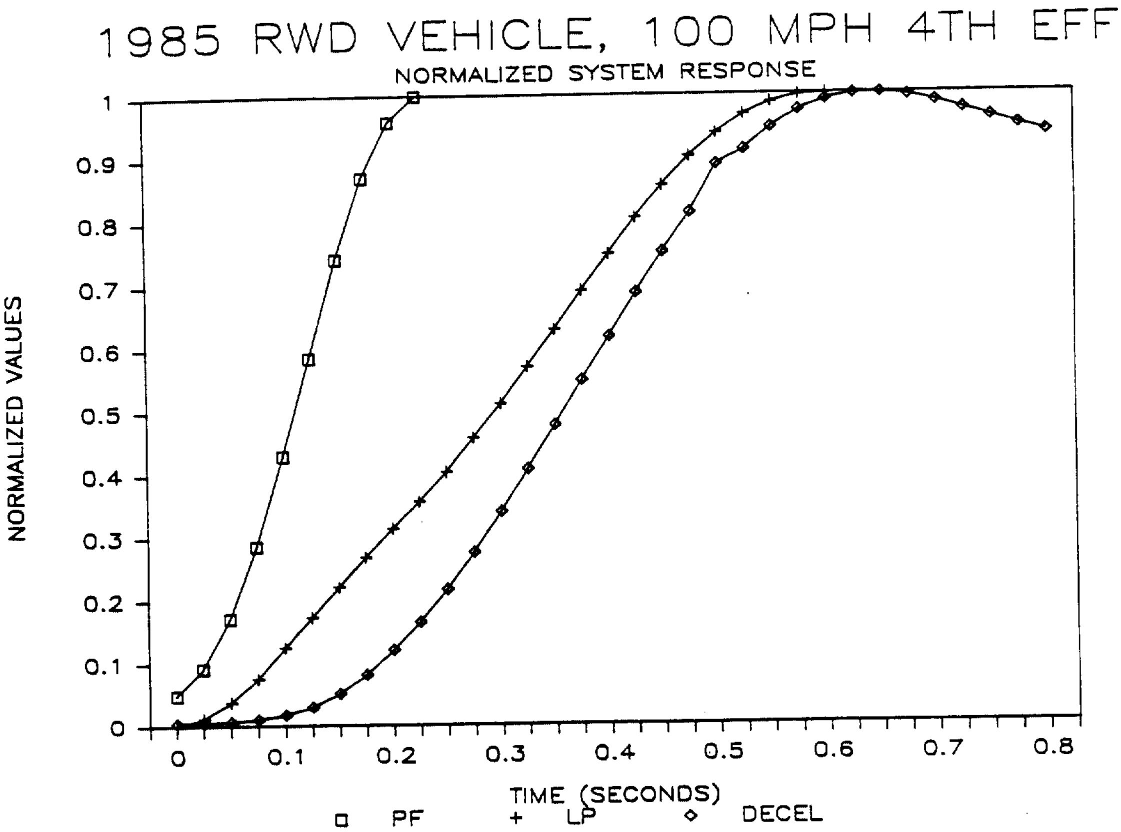


Figure 7

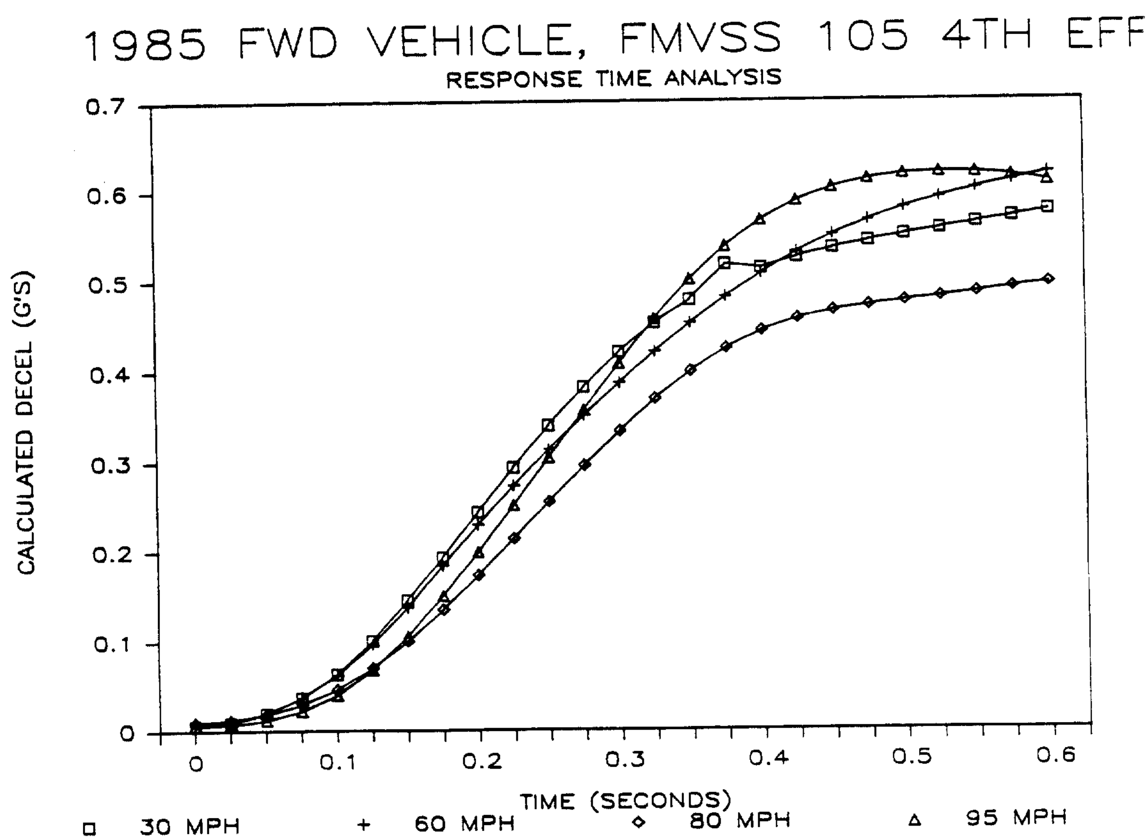


Figure 8

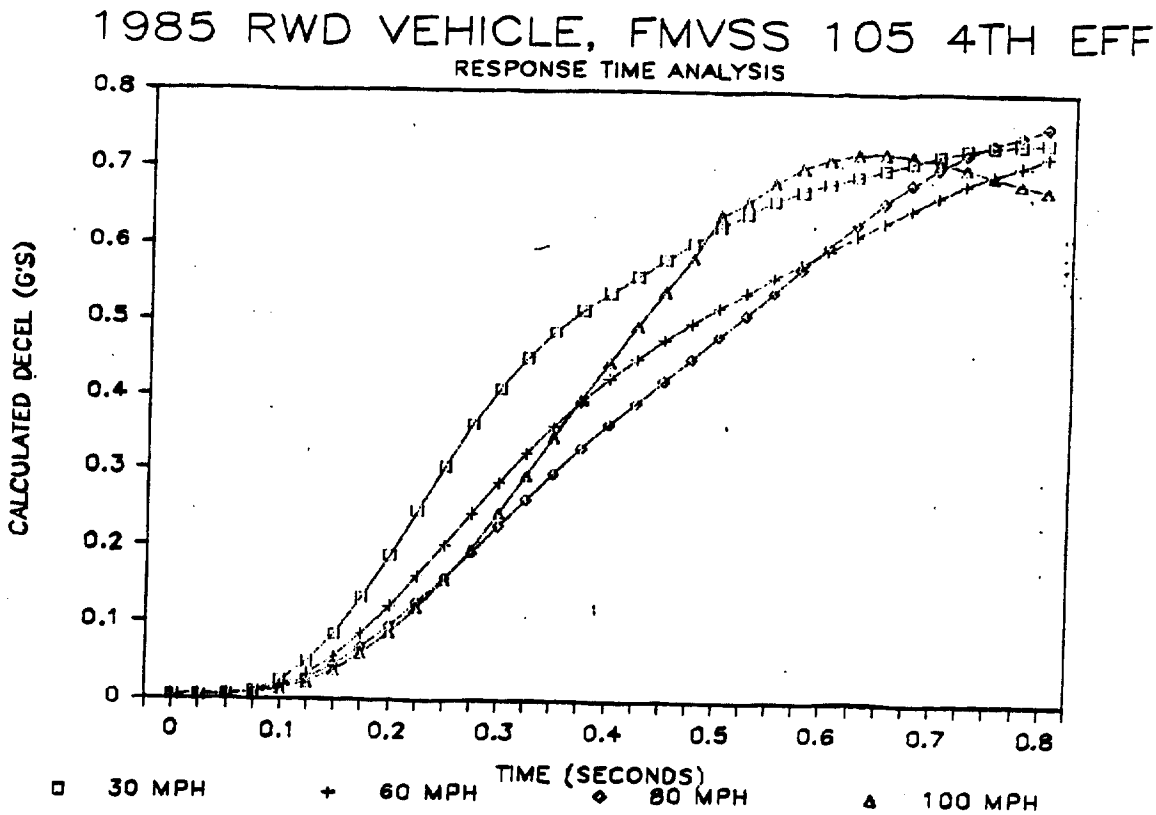

1985 RWD VEHICLE, FMVSS 105 4TH EFF
RESPONSE TIME ANALYSIS
CALCULATED DECEL (G'S)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
TIME (SECONDS)
30 MPH
60 MPH
80 MPH
100 MPH

Figure 9

BRAKE BURNISH

OBJECTIVE

This appendix conveys results of tests wherein brake specific torque was measured at several stages during the burnish of brake systems.

CONCLUSIONS

1- For the vehicles evaluated in the GM test program, semi-metallic front disc brakes increased in output after undergoing burnish. The magnitude of this increase varied among vehicles and was dependent upon the burnish procedure. Increases of over 100% were observed in short, high deceleration rate burnish procedures, while increases of the order of 40% were more typical for vehicles run to the current FMVSS 105 or the proposed FMVSS 135 burnish procedures. Asbestos friction materials on the disc brakes of these same vehicles decreased in output with burnish, typically by 20%.

2- For the test vehicles used in this program, equipped with drum brakes on the rear axle, rear brake output decreased with burnish. The decrease in output varied with rear brake design. The drum brake design encouraged by ECE R13 drops in output with burnish about 10% while the larger FMVSS 105 inspired drum brake design drops 30% in output after burnish. (See Appendix 16 for descriptions of the "105 inspired vehicle" and the "ECE R13 encouraged vehicle".)

RECOMMENDATIONS

A longer burnish than is proposed for FMVSS 135 is necessary. This is especially important since brake standard harmonization places increased emphasis on brake balance. The current provision for a 200 stop burnish in FMVSS 105 should be incorporated into the harmonized test.

DISCUSSION

The effect of brake burnish on vehicle brake system performance is an important brake design and test consideration. During the course of the testing related to FMVSS 135, GM has studied this effect on four GM vehicles and five competitive vehicles. Front brake specific torque values in the new pre-burnished ("green") condition were compared to similar values after burnish. All the vehicles tested had disc brakes on the front axle. One GM vehicle was tested with asbestos friction materials on the front brakes, the remainder of the vehicles used semi-metallic friction materials. A summary of the findings is presented in Figure 1. Here the percent change in front brake output from green to burnished condition is plotted as a function of the number of burnish stops. Several of the tests included only data after 36 burnish stops, and therefore, subsequent numbers of burnish stops have fewer data values. For the semi-metallic friction materials studied, the front brake output increased with burnish, the magnitude of the increase being dependent upon the particular vehicle and the choice of burnish schedule. In most cases, semi-metallic friction materials on the front disc brakes of a vehicle experience the largest percent change in output in a relatively few (less than 100) burnish stops.

The particular vehicle tested with asbestos friction materials of the front brakes showed a decrease in output with burnish. After 36 burnish stops, the average front brake output was down almost 20%, and subsequent burnishing (86 and 200 stops) produced smaller changes beyond this value.

Rear drum brake specific torque was measured for various burnish conditions. Two drum brake designs were evaluated, a smaller drum brake design compatible with the output requirements of a FWD vehicle configuration and a larger design compatible with the requirements of a RWD vehicle configuration. The torque of the FWD drum brake design was reduced by 10% after burnish, while that of the RWD design was reduced by 30% after burnish. The results of these tests are shown in Figure 2.

The use of asbestos friction materials on front disc brakes has been effectively precluded by the stringent fade schedule of FMVSS 105, the limit of 15 pounds (66.72 N) on recovery pedal force, increased fuel economy requirements, tighter packaging of the brake components within the smaller wheels used today, and other factors that reduce brake cooling. Only very large vehicles with substantial front disc brakes, and a very few small automobiles are able to comply with FMVSS 105 with asbestos friction materials on the front disc brakes.

Drum brakes used on the rear axles of domestic vehicles almost universally rely upon asbestos friction materials. While many candidate asbestos replacement materials are under development, an acceptable substitute for asbestos friction materials for use with drum brake applications has not been identified at this time.

With the prevailing use of semi-metallic friction materials on the front disc brakes and asbestos friction materials on the rear drum brakes of most domestic passenger cars, a manufacturer must deal with a green brake system that has 40% lower output on the front brakes and 10 to 30% higher output on the rear brakes compared to the burnished brake system. As discussed in Appendix 16, Pre-burnished Brake Effectiveness, these green brake conditions coupled with the laden loading condition testing of FMVSS 105 actually encourage the use of rear drum brake designs that undergo a large change in output with burnish.

The proposed FMVSS 135 places increased emphasis on brake balance. Since brake balance is so significantly affected by front and rear brake torque output, it is obvious that torque output must be stabilized before testing of any balance dependent parameter can be considered valid or indicative of in use vehicles. Recognizing, however, the necessary constraints that make very lengthy burnish procedures impractical, GM recommends that the 200 stop burnish cycle currently included in FMVSS 105 be incorporated in the new harmonized standard.

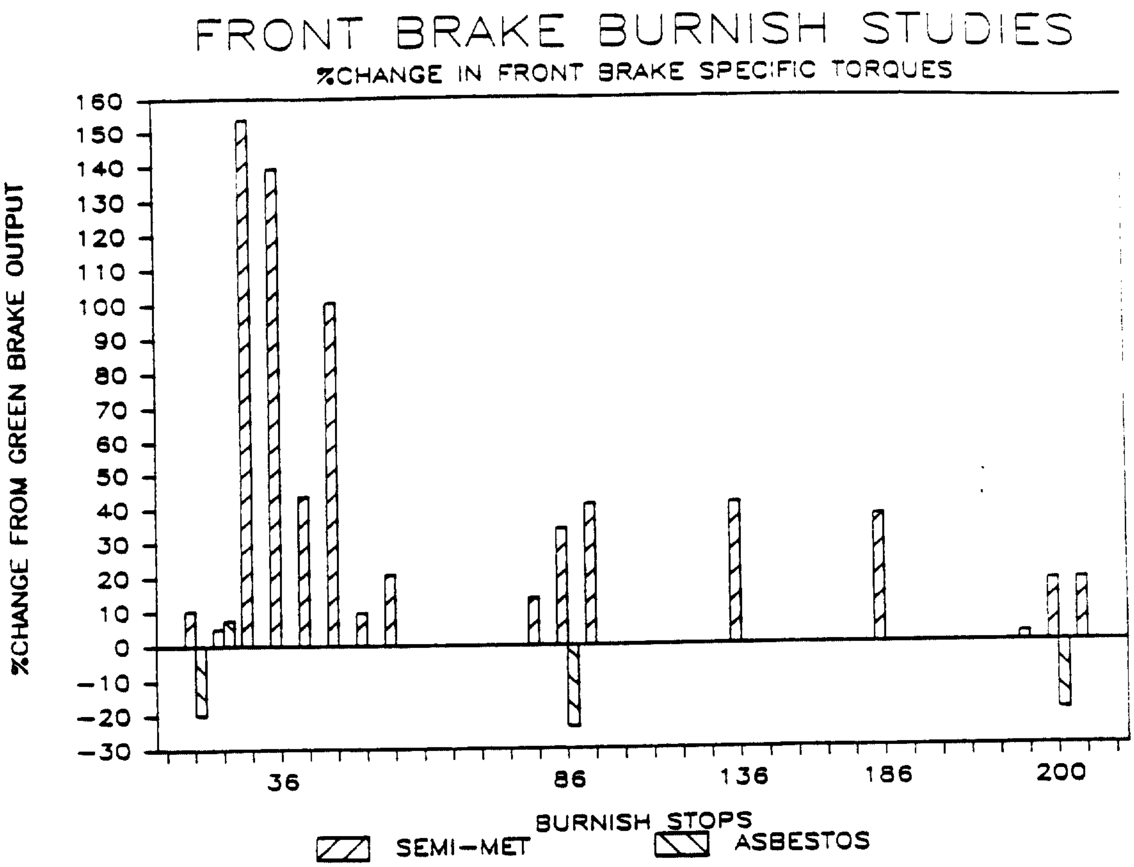


Figure 1

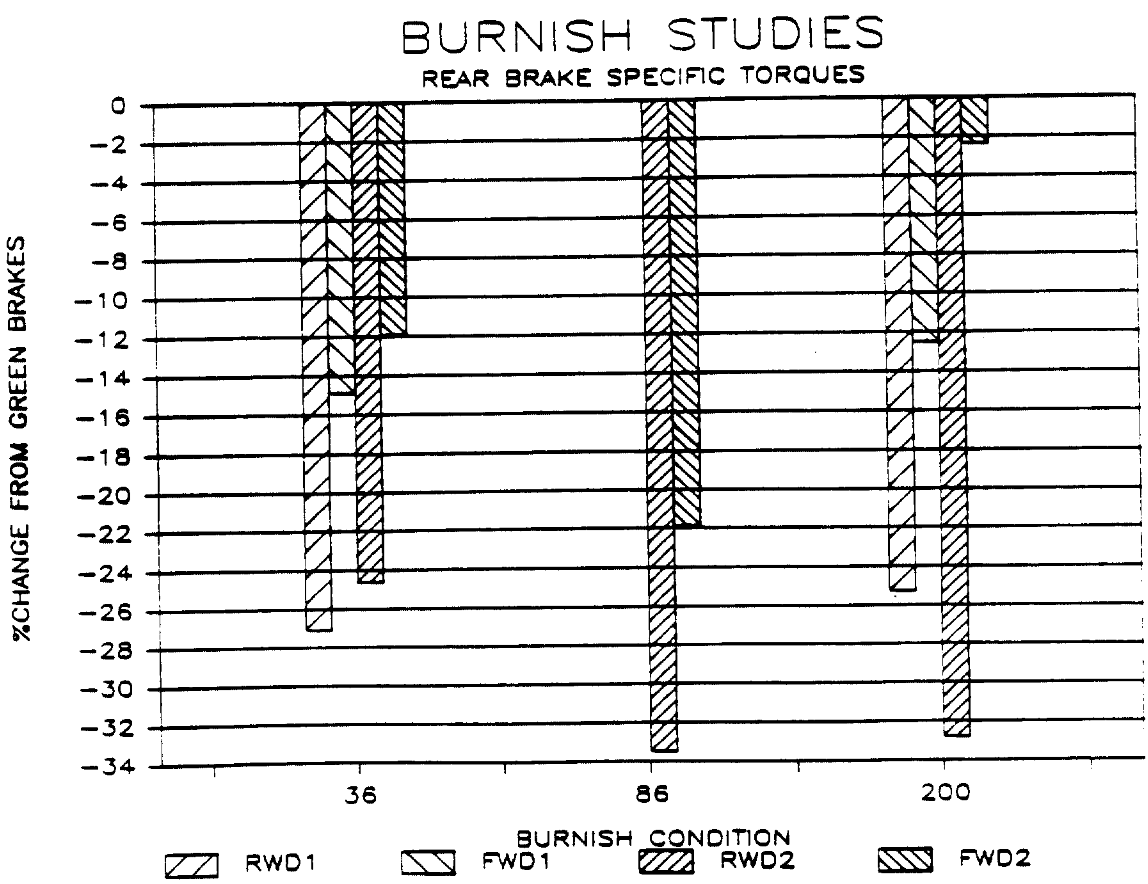


Figure 2

TIRE BURNISHING

OBJECTIVE

The purpose of this Appendix is to summarize recent GM experience with tire burnishing and its effect on peak traction coefficient as a result of brake testing, customer usage, and traction testing.

CONCLUSIONS

1. Green (as manufactured and delivered) tires exhibit relatively large changes in dry peak brake traction as a result of brake testing.

2. The magnitude and rate of change in peak dry traction coefficient as a result of brake testing or with usage is influenced by tire design, test road surface, and degree of longitudinal slip experienced by the tire.

3. Tire burnishing on a vehicle is influenced by brake force distribution. Rear tires burnish at a slower rate than front tires. Further, rear tires on a vehicle with a front biased brake balance burnish at a slower rate than on a vehicle with a rear biased brake balance. Rear tires usually have lower dry peak traction than front tires throughout a FMVSS test sequence.

4. Manufacturing, shipping, and delivery processing of vehicles provides a degree of tire burnishing.

5. Vehicles with 10,000 to 20,000 miles (16,000 to 32,000 km) of fleet usage appear to have tires in a burnished condition. Front to rear differences in tire burnish for vehicles in

fleet usage may be clouded by tire rotation.

6. Lack of tire burnish is likely to influence pre-burnish brake effectiveness performance results.

7. A potential method of resolving tire dependent brake performance uncertainties is to adjust the preburnish effectiveness and brake balance requirements to account for the variation in peak tire-road traction coefficient. Another alternative is to allow the use of pre-conditioned test tires or a longer burnish procedure similar to that of the current procedure in FMVSS 105.

RECOMMENDATION

1. NHTSA should either eliminate the preburnish effectiveness requirements or revise them significantly. Further the brake burnish procedure should be revised to allow tires to burnish and attain a stable peak dry coefficient before effectiveness tests are conducted.

2. Alternately, the concept of using "pre-burnished test tires" for brake testing should be considered. However, this approach is expensive and therefore, least desirable and should only be considered if other solutions are not acceptable.

DISCUSSION

GM conducted an extensive series of brake and tire tests directed at understanding FMVSS 135 as it compares to the FMVSS 105. The program included brake tests of front wheel and rear wheel drive, six passenger vehicles together with traction trailer measurements of tire peak traction before and after brake testing. These initial results prompted a further review of existing tire data and additional tire tests directed at green tires and dry peak traction.

In addition to the special tests conducted for this response, GM has a tire traction test program, associated with the release of production tires. A special traction test facility, located at Automotive Proving Ground in Pecos, Texas is used for these tests. Each tire sample is first submitted to a series of wet traction tests at prescribed speeds and water depths. The dry traction part of the test sequence is always run after the wet testing is completed. This test sequence has tended to obscure the sensitivity of tires to burnish as tire development has moved through several generations of radial tire technology.

Peak Traction Changes, Green-to-Burnished

Tire-road peak dry traction coefficient of the original equipment tires ranges from 0.7 to 0.9 as indicated in Appendix 7, Tire Design Considerations. More importantly, the mean value of the peak coefficient changes as the brake test progresses from the preburnish instrument check through final effectiveness test. Further, the degree of this change is different for the front tires as compared to rear tires.

The phenomenon of tire burnishing can be most conveniently examined with traction trailer testing. This approach involves ten replications of a ramp brake (or longitudinal slip) application to each test tire for a particular road surface condition. Figure 1 shows typical data resulting from application of this procedure to a modern tire on a brake test road surface. Results indicate an average increase in peak traction coefficient of 20% from green condition to the end of ten cycles. Although the test includes some locked wheel sliding, this is minimized, and the resulting tread flattening is not thought to be a factor in the response of the tire to burnishing.

Tires tend to lock at random locations for this degree of testing.

Road and Tire Construction Influence on Burnishing

Figures 2 and 3 compare a number of typical original equipment passenger car tires on a test road surface at the Automotive Proving Ground (APG) in Pecos, Texas with similar tests on a brake test road surface at GM's Desert Proving Ground (DPG) in Arizona. All tires except the one noted 'sporty', are current technology low rolling resistance tires. The tire noted 'sporty' is a high traction tire released for a high performance car. These data illustrate the complexity of tire burnish effects. The burnish rate, as evidenced by this study, is strongly influenced by tire design and the nature of the test surface. An increase in peak coefficient from an average of 0.78 to an average of 0.91 was observed as a result of ten cycles.

Past data, taken on public roads, was analyzed and plotted in Figures 4 and 5. These figures apply to two different tire constructions tested on a variety of public and Proving Ground road facilities. A set of green (unburnished) tires were used for each test and peak traction was measured for eight traction stops. The strong influence of both road surface and tire design is very evident from these data. The large road influence on peak traction for a particular tire design should also be noted. The available data show that the road surfaces have varying influences on braking traction.

Influence of Brake Testing on Tire Burnish

Figures 6 and 7 show traction data on sets of tires removed from two types of vehicles after completion of FMVSS 105 testing. The P205/75R15 tires in Figure 6 were fitted to a six passenger rear wheel drive car with its brake balance developed in the late

1970's. The P205/75R14 tires in Figure 7 were fitted to a six passenger front wheel drive car with its brake balance developed during the early 1980's.

Figure 6 indicates that there is no discernible difference between the average peak coefficient values of front and rear wheel position P205/75R15 tires removed from the rear wheel drive cars. However, Figure 7 indicates that the average peak coefficient values of front wheel position tires are significantly higher than the average peak coefficient values of the rear wheel position tires removed from the front wheel drive cars. These results indicate that the burnishing experienced by the tires varies with the type of tire design and possibly with the type of car. Further, the front tires on a front wheel drive car are burnished to a greater degree than the rear tires. General Motors believes that this variability in peak traction coefficient resulting from burnishing effect could influence the stopping distance performance of vehicles.

Another series of tests were conducted to obtain a preliminary map of the tire burnish effects at various stages of FMVSS 105 test sequence. This test program is referred to as "Time Traction Profile Study" which is illustrated in Figure 8. Multiple sets of tires were fitted to a front wheel drive car and removed after completion of various stages of the FMVSS 105 brake test with each set starting from the beginning of the brake test sequence and completing the stage indicated in Figure 8. Figure 9 and 10 summarize the traction results for front and rear wheel position tires removed at various stages of the brake test schedule. For reference purposes, similar tires fitted to a new similar car were obtained from a GM dealership and tested for traction. It appears from these limited results, with one tire construction, that substantial tire burnishing occurs during the same part of the test that is used to burnish brakes. Peak traction values at the beginning of the preburnish test (after the instrument check step) are about same as green condition values. Further, it appears that the tires experience some degree of burnish before reaching the dealership. This limited data imply that tire burnish may not be of practical concern to the customer since the usage associated with assembly and transportation provides a degree of burnish to the tire. However, new test tires are clearly not in a burnished condition at the time of the preburnish effectiveness test and this will have a potentially significant influence on these test results.

General Motors recognizes that NHTSA compliance testing is conducted on cars delivered through a dealer and so are likely to have tires with some degree of burnish. However, it is possible to have tires in green condition at the dealership, particularly when tires are changed by the dealer to an optional size or to a different original equipment brand. Therefore, GM cannot feel confident of dealer delivery level of tire burnishing and must account for the possibility of tires being at green peak traction level for brake compliance testing unless some provisions are incorporated into FMVSS 135 to provide some tire burnishing.

High Mileage Tires From Vehicles in Fleet Service

Figures 11, 12, and 13 show the peak traction condition of tires removed from vehicles in fleet service with mileage in the range of 10,000 to 20,000 miles (16,000 to 32,000 km), using the same ten lock up skid testing procedure used in Figure 1 thru 7. These data show no trend indicating that further increases in peak coefficient is occurring at this vehicle mileage.

Discussion of Recommendation

NHTSA should recognize that the amount of peak traction available at the tire-road interface influences the best stopping distance achievable during the effectiveness tests. Further the condition of no wheel lock up specified in the proposed FMVSS 135 constrains the driver from utilizing all of the available traction during preburnish test or to recognize the fact that peak traction has improved and therefore, better post burnish effectiveness performance can be obtained.

General Motors believes that a regulation for which performance is highly influenced by the tire burnish is inappropriate until and unless the burnish effect is understood and appropriately addressed. Therefore, the preburnish effectiveness provisions of FMVSS 135 should be eliminated, or the stopping distances should be lengthened to account for the lower peak traction values which exist in brand new tires.

TWS Traction Testing
New "Green" P205/75R14
Testing Conducted on MPG N/S Straightaway
Based on the Average Values of 4 Tires

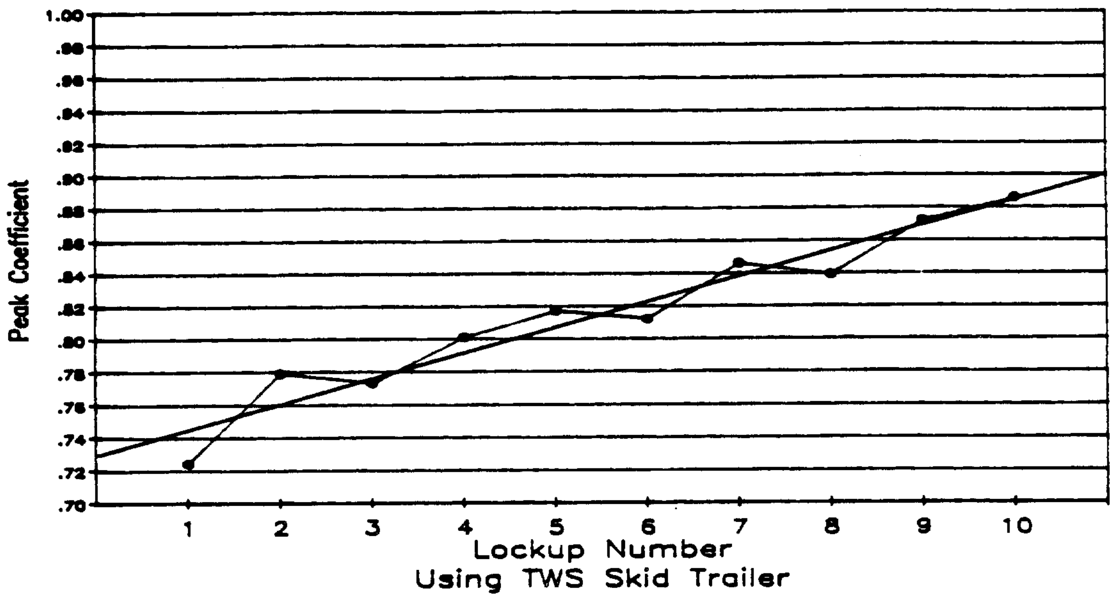


Figure 1

TWS Traction Testing

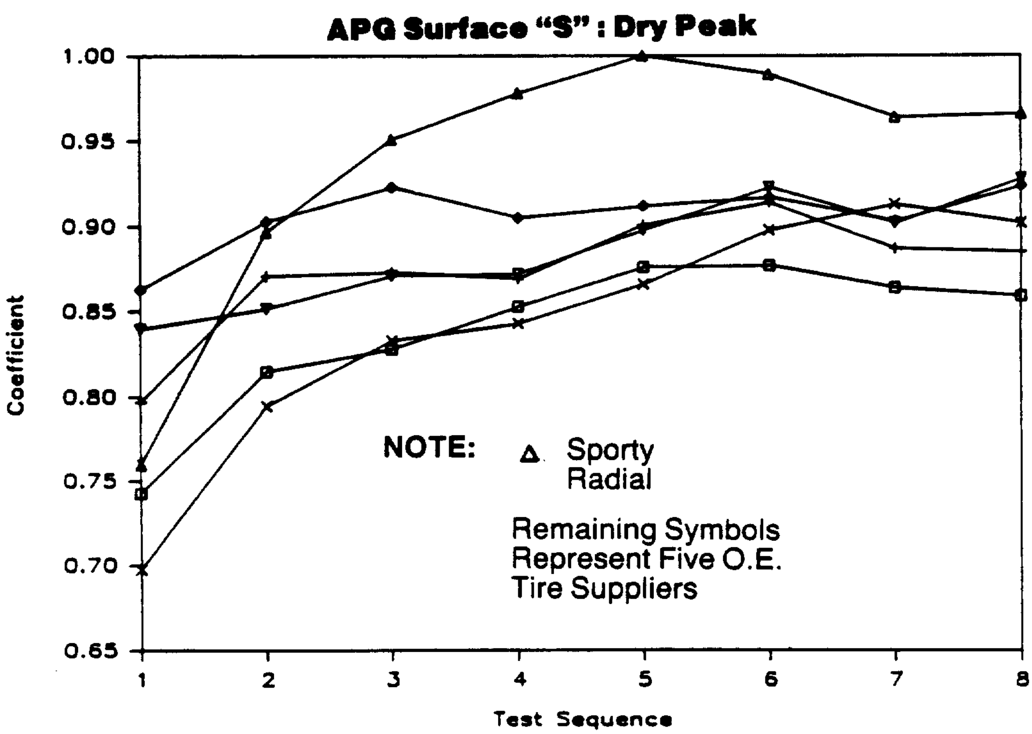


Figure 2

TWS Traction Testing

DPG Surface "105" : Dry Peak

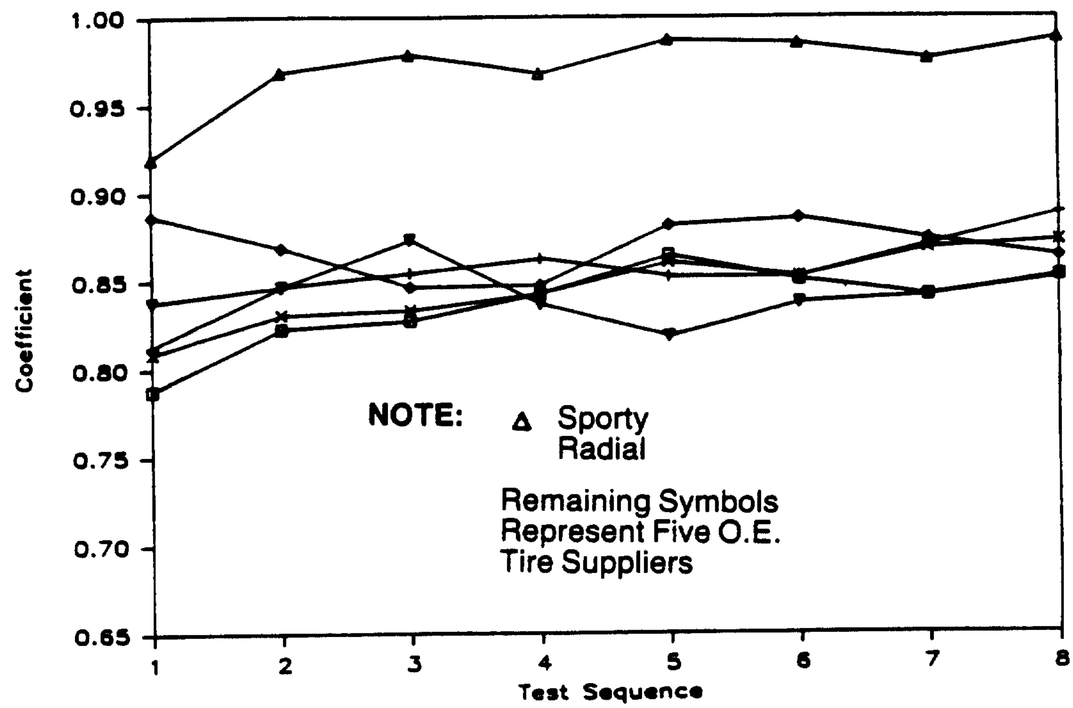


Figure 3

TWS Public Road Braking Traction Study

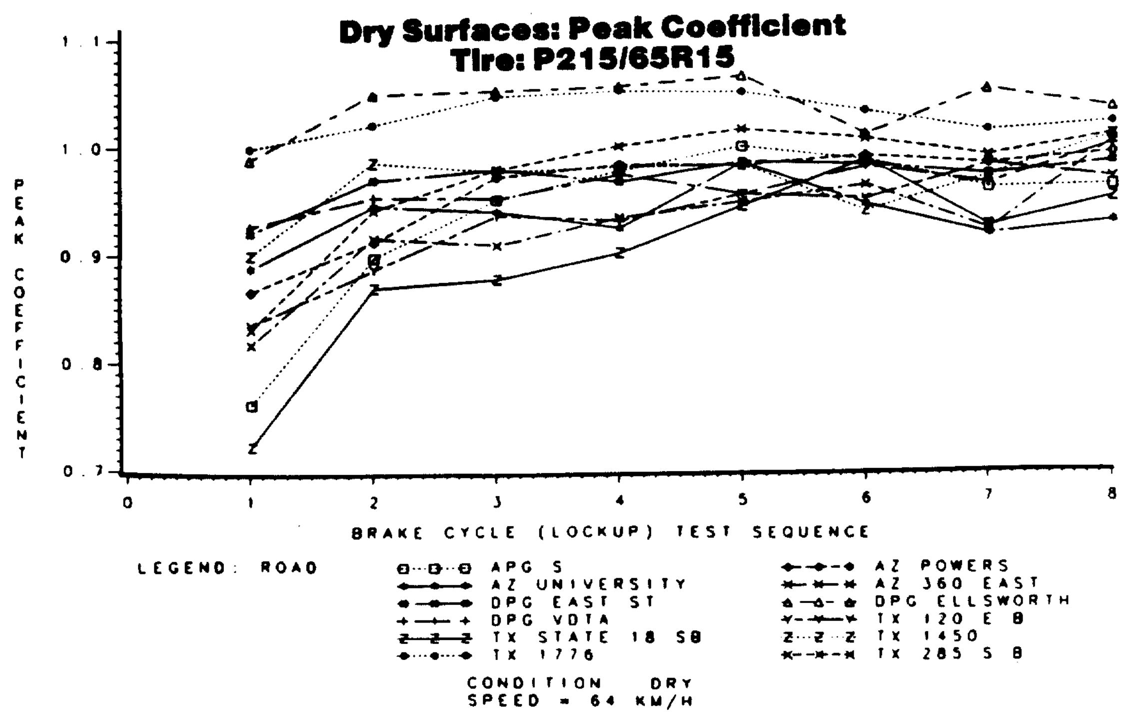


Figure 4

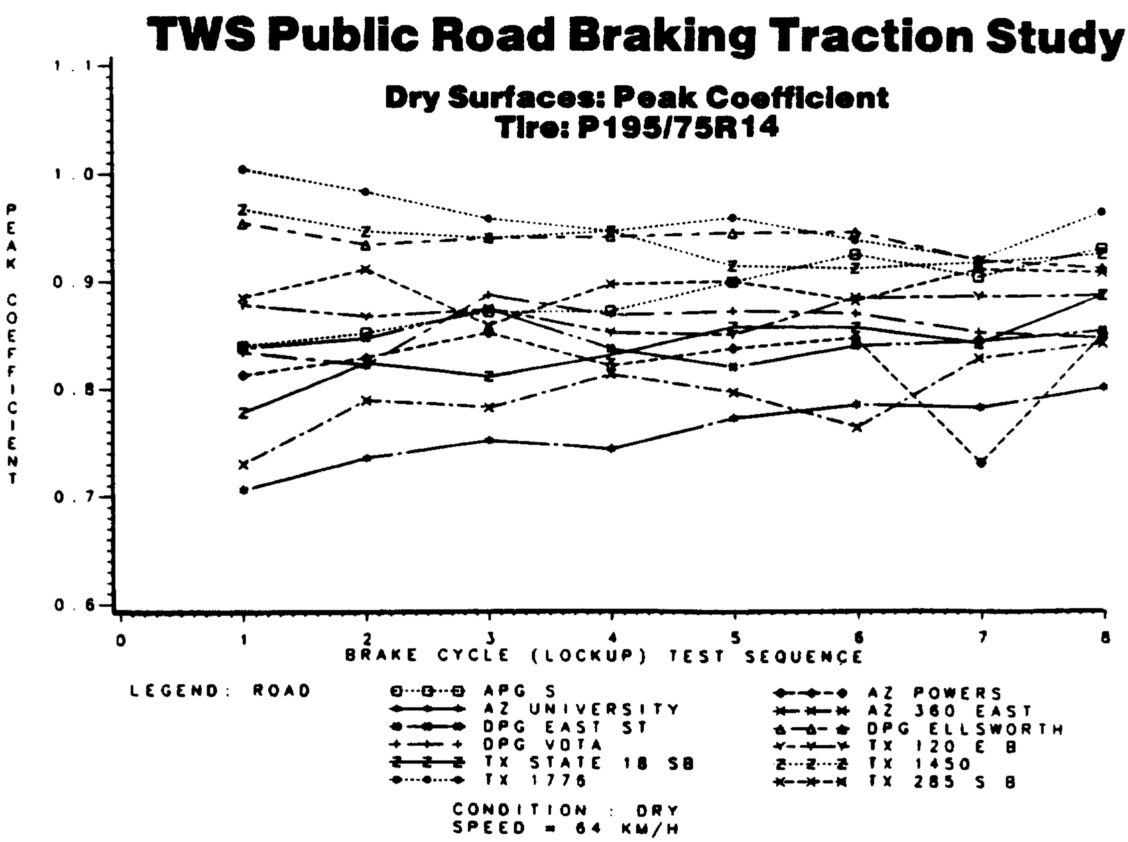


Figure 5

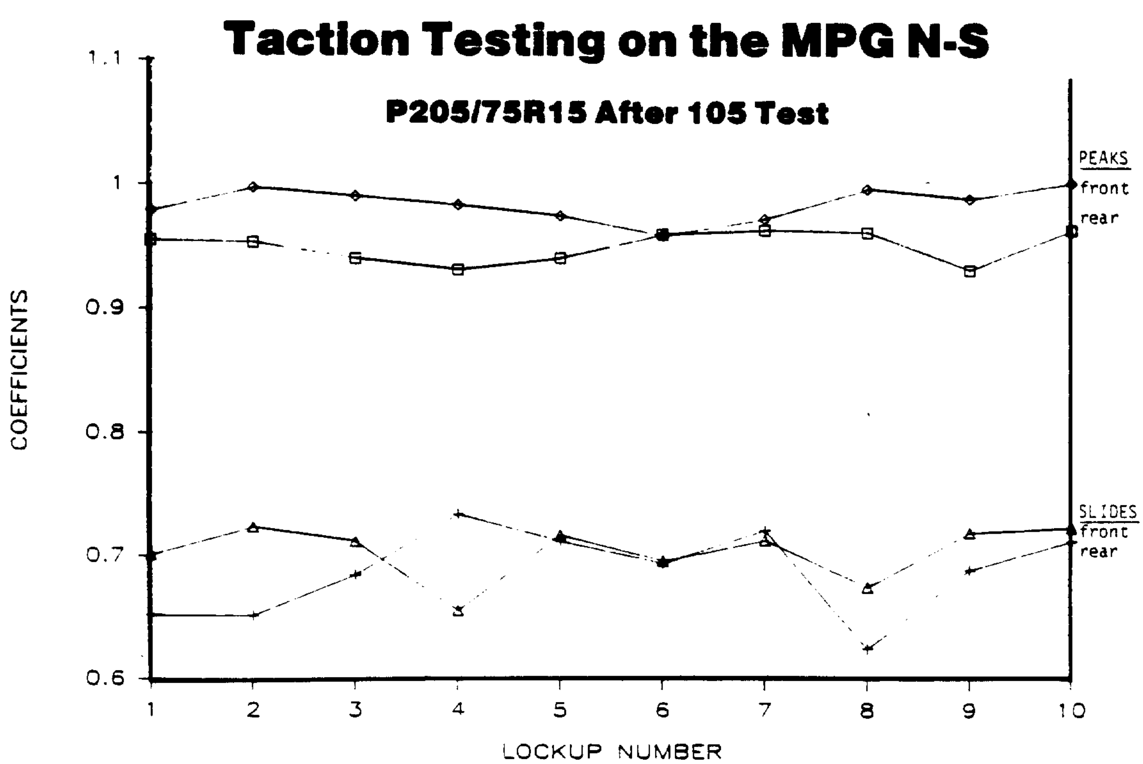


Figure 6

Taction Testing on the MPG N-S

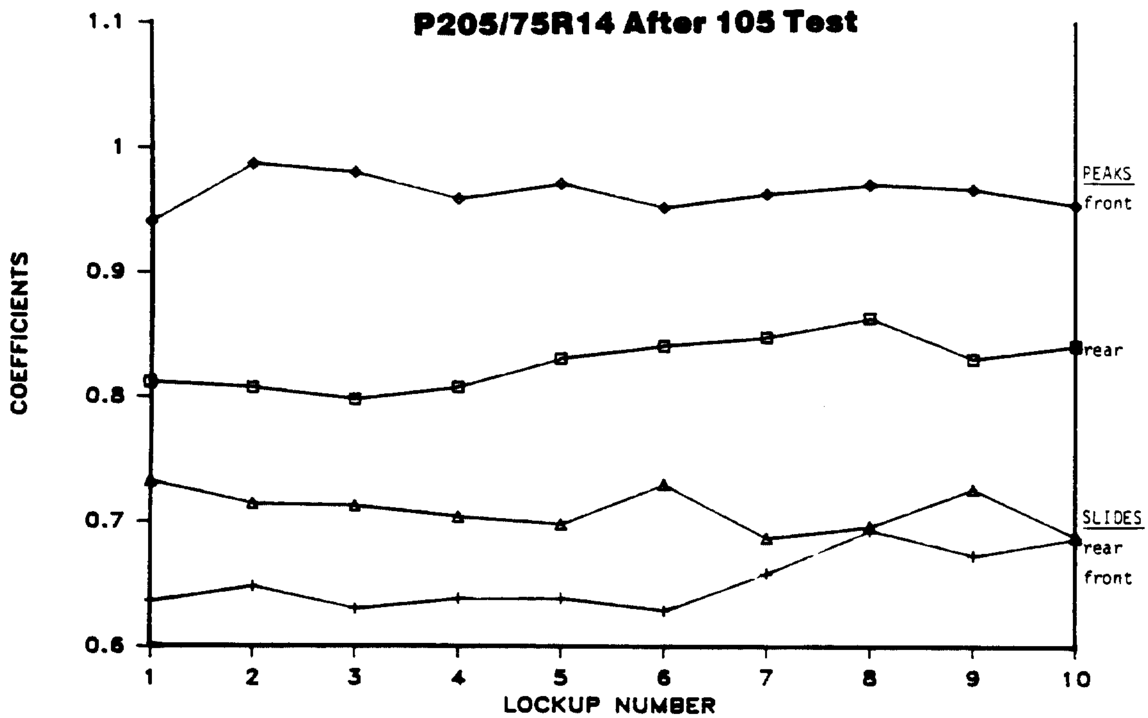


Figure 7

FMVSS 105 Time Traction Profile Study

Effect of FMVSS 105 Test Schedule on Tire Coefficient Level

- Tires: P205/75R14
- Method

1. Conduct first segment of stopping distance test
2. Measure braking traction coefficients on first tire set
3. Repeat stopping distance test from the beginning with a new set of tires and continue thru second segment
4. Measure second tire set on skid trailer
5. Repeat procedure for each segment of stopping distance test until coefficient measurements stabilize

FMVSS 105 Test Schedule

Instrument Check	1st Effectiveness	First Burnish	2nd Effectiveness	Fade & Recovery Burnish	3rd Effectiveness	Burnish

Braking Traction Test Schedule

- New Green Tires

--------• After Instrument Check

------------------• After 1st Effectiveness

------------------------• After First Burnish

---- Tentatively Scheduled --------------• After 2nd Effectiveness

---- Tentatively Scheduled ----------------------------• After F&R Burnish

---- Additional Tests will be conducted (if required) ------------------•

Note: Tentatively scheduled tests will be conducted only if required, this will be based on the results after the first burnish test is completed.

Figure 8

TWS Traction Testing, MPG N/S
FMVSS 105 Time Traction Profile,
Front Tires P205/75R14
Predicted Range During Test and Average

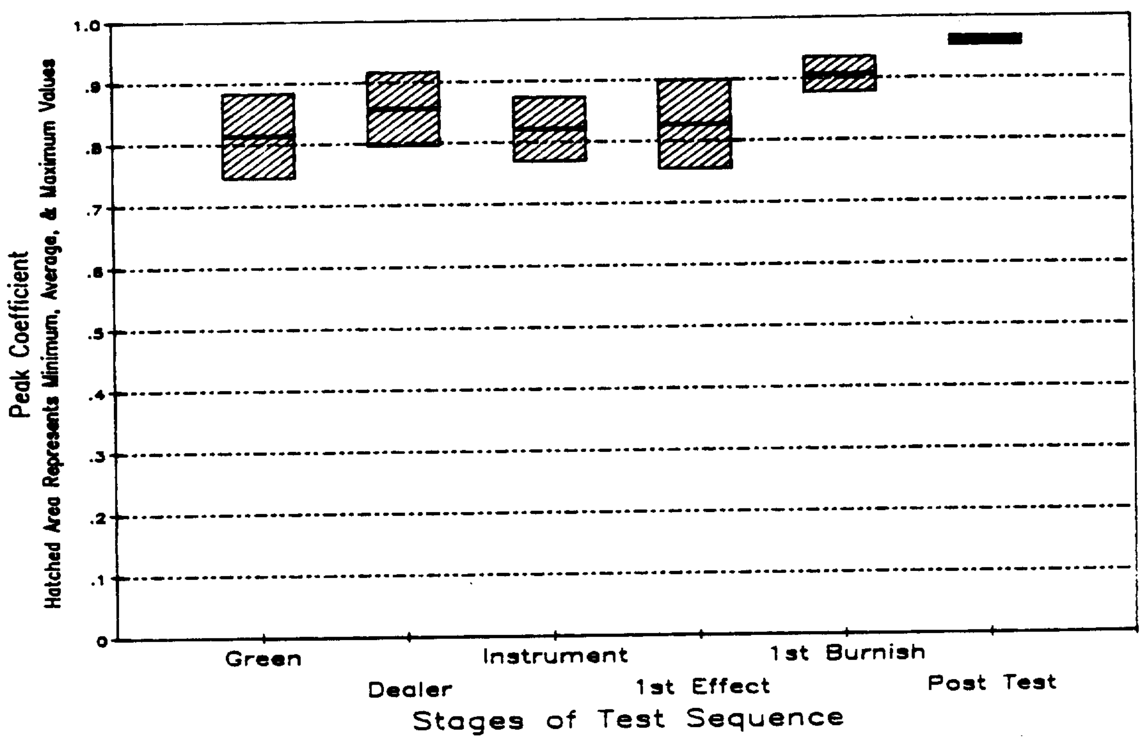


Figure 9

TWS Traction Testing, MPG N/S
FMVSS 105 Time Traction Profile,
Rear Tires P205/75R14
Predicted Range During Test and Average

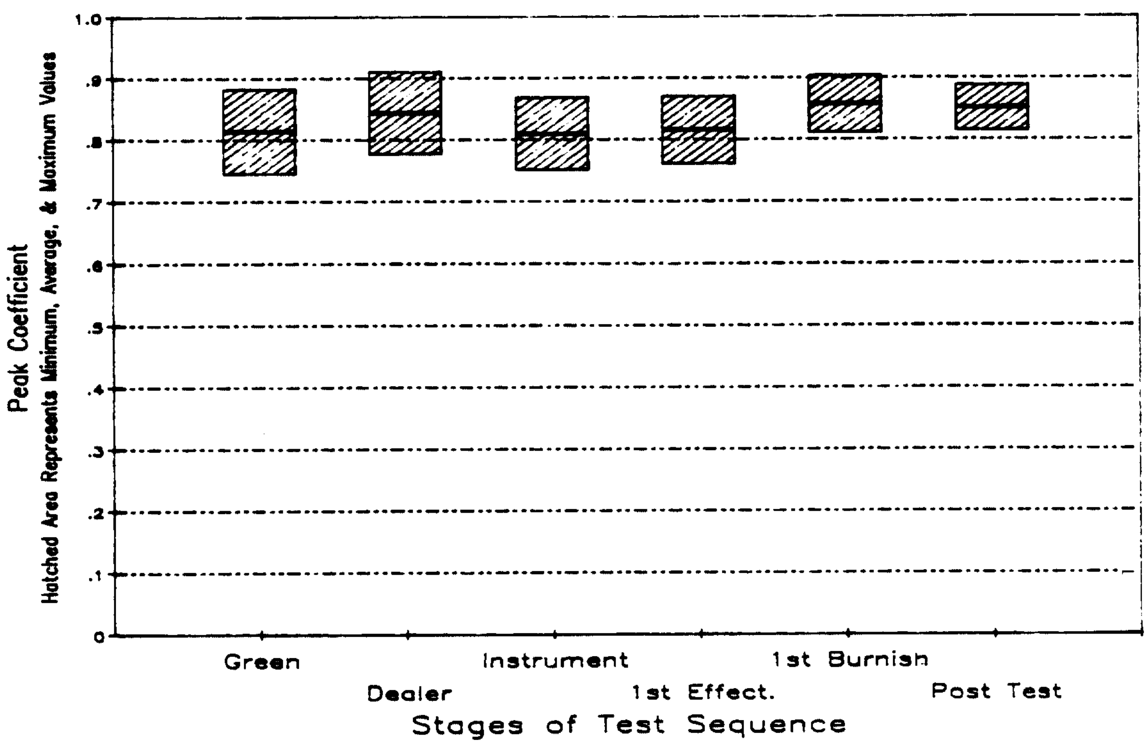


Figure 10

TWS Dry Peak Braking Traction P205/75R14

Right Front with 11681 Miles
Tire Taken From a Fleet FWD Medium Car

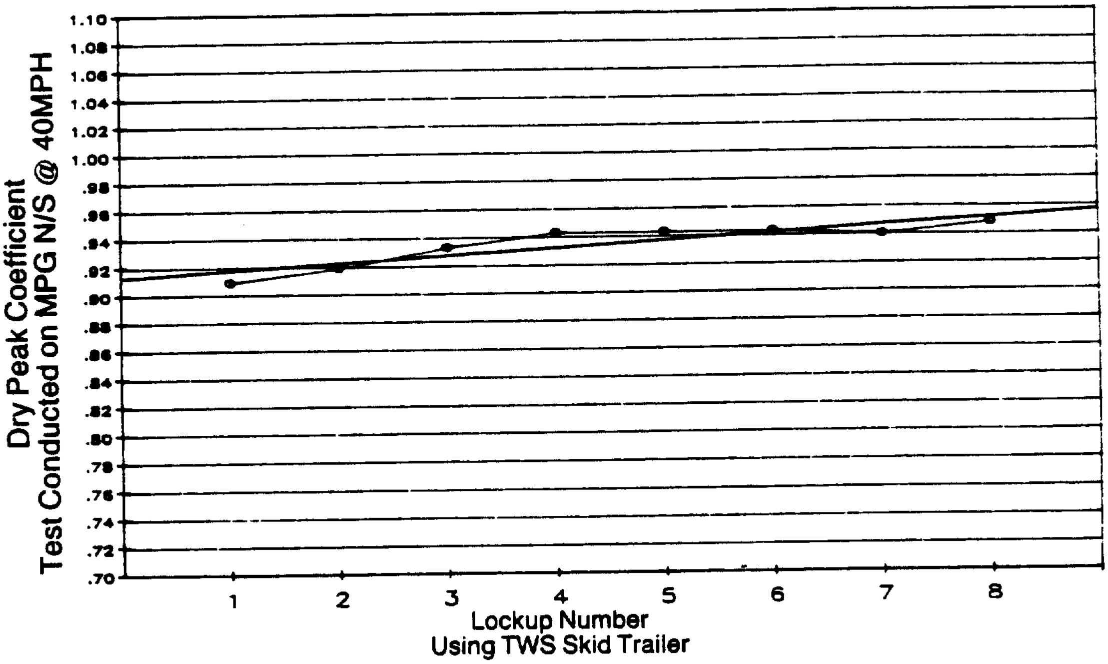


Figure 11

TWS Dry Peak Braking Traction P205/75R14

Right Rear with 119622 Miles
Tire Taken From a Fleet FWD Medium Car

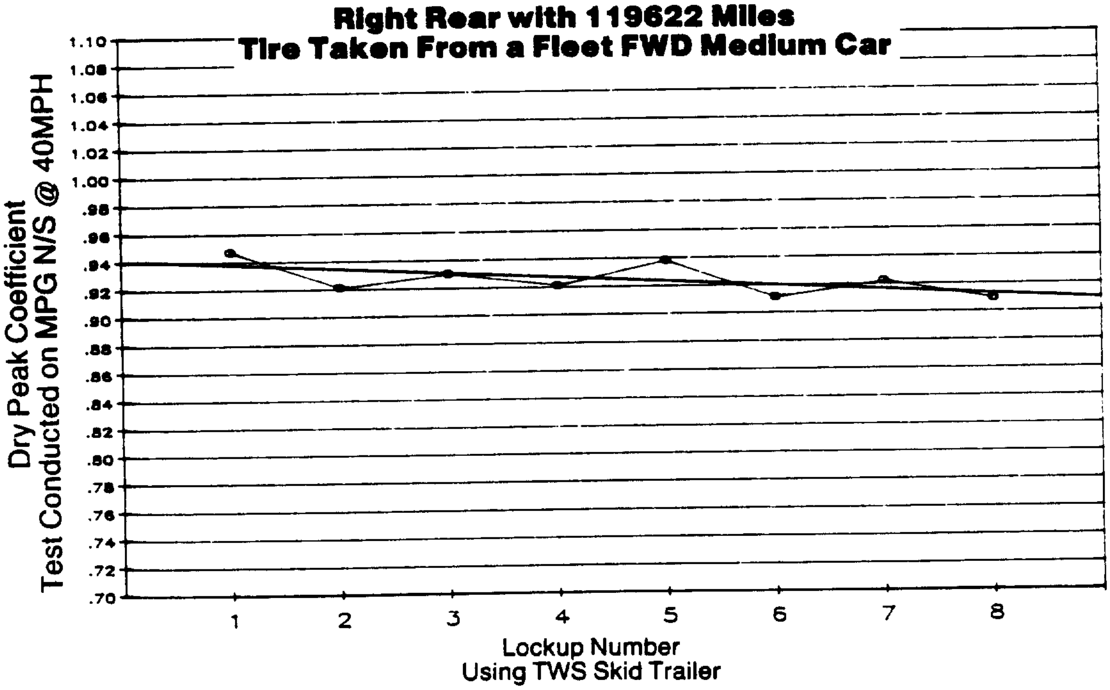


Figure 12

TWS Dry Peak Braking Traction P205/75R14

Right Front with 19622 Miles
Tire Taken From a Fleet FWD Medium Car

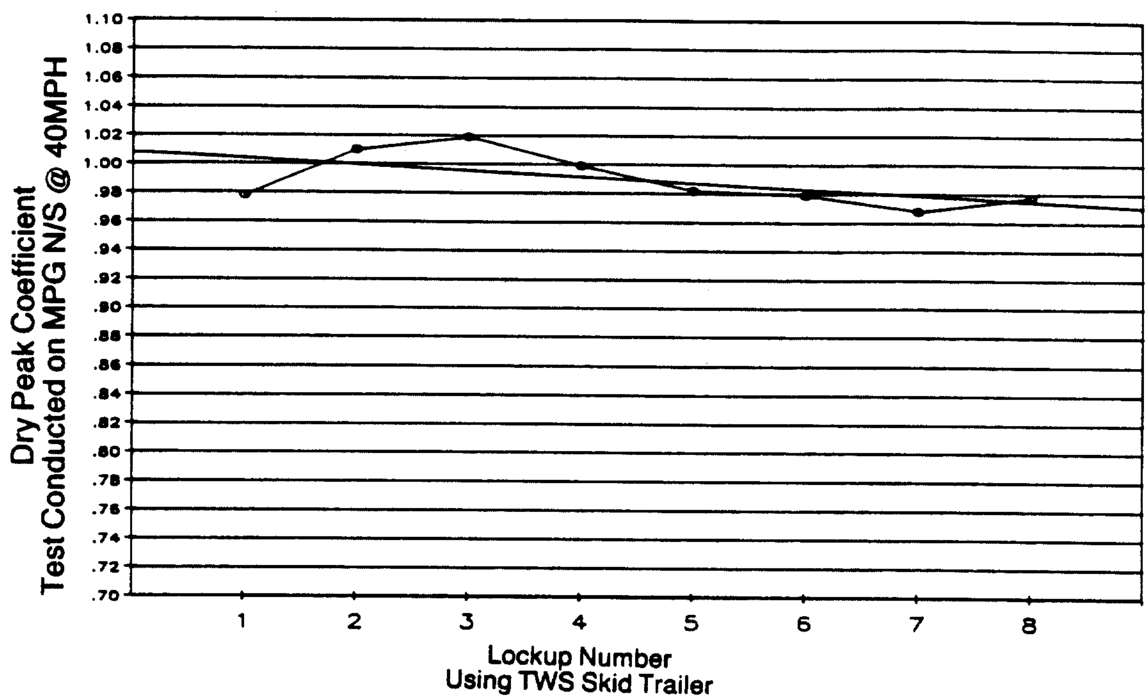


Figure 13

VARIABILITY

OBJECTIVE

This Appendix deals with the issue of variability in terms of both vehicle brake balance and stopping distance. It reviews the vast data GM has obtained with regard to the issue of brake system variability, discusses its relevance to the proposed FMVSS 135, and discusses various approaches that might be taken to deal with this phenomenon.

CONCLUSIONS

1. Vehicle brake balance variation is a natural consequence of the mechanism of friction and real world friction materials, as well as the vehicle loading condition, temperature of the brake elements, and degree of burnish.

2. GM tests have established a minimum range of 10 percentage points in vehicle brake balance variation in new vehicles prepared in a precise 200 stop burnish, and tested in a minimum dispersion procedure. It must be recognized that this variation in brake balance increases the theoretical minimum stopping distance of vehicles.

3. The performance requirements of R.88 represent a pass margin above theoretical minimum of only 7.4% when brake balance certification is established by design calculation of the nominal vehicle and less than 3% when the brake balance certification is established by physical test. The latter is unacceptable in a self certification standard.

RECOMMENDATION

The agency should review FMVSS 135 with regard to the issue of vehicle variability and adjust the stopping distances accordingly. This will require a definition of the method to be used to certify vehicle brake balance and the test procedure, if any, to be employed. Considerable vehicle testing will be required to validate the minimum range in brake balance if the extent of burnish or the test procedure differ significantly from those employed by GM during its test program.

DISCUSSION

Variability, What It Is and Why It Exists

Variability in braking systems performance arises from at least five different sources: part to part manufacturing tolerances, friction material heterogeneity, vehicle loading condition, degree of burnish, and the temperature of brake elements. When discussing this subject, care should be taken to distinguish between variability in brake balance, and variability in stopping distance. Likewise, a distinction between variability in a single vehicle, multiple vehicles of the same family, and between vehicle families must be made. Finally, the magnitude of variation in either brake balance or stopping distance is test procedure dependent, and proper treatment of this subject will recognize this dependency.

To begin, consider a single brake assembly (either a disc or a drum) and the sources of variability in output of this simplest system. First, recall that friction as a process is inherently stochastic, i.e., the value of friction force at any instant of time can only be predicted within certain statistical limits. This fact establishes the ultimate minimum of variability.

Second, the output of a single brake is influenced by the degree of burnish that exists at the time of test. Third, the temperature of the friction elements adds a third source of variability in this single system.

To expand upon this discussion, consider two brake assemblies on a single axle of a vehicle. By normal practice, these two brake assemblies will be nominally equivalent. Beyond the previously mentioned sources, the manufacturing tolerances between brake assemblies and the normal variation in friction materials are additional sources of variability. In this case, differences would manifest themselves as side to side torque variations at a single axle. Quality control practices strive to reduce the variation in the physical dimensions of parts making up a brake assembly. The heterogeneity of friction materials makes reductions in variability of this type more difficult. The largest effect of these variations is expected to occur during the very earliest usage, and while of small importance to the customer in long term performance , it is a strong influence in an FMVSS test, which effectively evaluates only new brake performance.

To continue, consider a single vehicle equipped with brake assemblies of different design and with different friction materials on each axle (the common configuration in the North American market). This situation would include a vehicle with disc brakes on the front axle, equipped with semi-metallic friction materials, and drum brakes on the rear axle equipped with asbestos friction materials. In this case, most vehicle configurations do most of the brake work at the front axle, and thus temperature variations in the front brake elements are expected to be larger than those in the rear brake elements. Front brakes are also affected by air flow for brake cooling in a different manner than rear brakes. Likewise, the front brake elements are normally expected to burnish more quickly than those on the rear, simply because the accumulated energy in the front brakes increases more quickly. Finally, the thermal sensitivity of friction materials may be different in disc brake designs than in drum designs. These differences provide additional sources of variability which are not reduced by zealous application of quality control procedures.

With regard to vehicle brake balance, the total variations discussed so far will produce differences in the distribution of braking forces between the axles of a single vehicle. The degree to which brake balance is affected by variations in output of individual brake assemblies is strongly influenced by the nominal distribution of brake forces between the axles. To illustrate this point, consider this simple example. If a vehicle is equipped with brakes on only one axle, say the front for discussion, then the brake balance of that vehicle is completely insensitive to variations in output of the front brakes. The nominal brake balance of this hypothetical vehicle is always 100% front brake, and a reduction of 50% in front brake output leaves the vehicle's balance at 100% front. So long as pedal force limits are not encountered, the stopping distance capability of such a hypothetical vehicle is also unaffected by variations in brake output, since the ultimate deceleration capability of this vehicle is simply limited by the peak traction coefficient of the tire to road interface.

To carry this idea forward, a general rule of thumb can be offered. This rule would state that the more a vehicle's distribution of brake forces between the axles is biased toward one axle, the less its brake balance and stopping distance are affected by variations in output at a single axle. The more nearly a vehicle has weight distribution and brake force equally distributed between the front and rear axles, the more the vehicle's brake balance is influenced by variations in brake output at a single axle. To illustrate this point, consider the example FWD vehicle used for this response. The brake efficiency at first axle lock for the nominal vehicle and with a 30% reduction in front brake output are plotted in figure 1. Here, the normalized brake efficiency at first axle lock is reduced by about 10% over most of the deceleration range, even though a 30% reduction in front axle output was assumed. A similar comparison is also made in figure 1 where a 30% increase in front axle output was assumed. Here, an increase in the dominant axle output produces an even smaller change in brake efficiency at first axle lock. The general observation to be made from this example is that the degree to which brake balance, and thus stopping distance, are influenced by variations in brake output is a function of the nominal distribution of brake forces between the axles, and for most vehicles, will be smaller in magnitude than a cursory examination might predict.

Variations in brake balance between vehicles of the same family are thought to result from normal manufacturing variations in part dimensions and friction material composition. An additional source of variation within a single family of vehicles is the static weight distribution of various vehicles within that family. For example, a single brake system is normally applied to vehicles that will have a wide range of option content, and perhaps even a range of passenger and luggage capability. Two vehicles in the same family might have a spread in static weight distribution of from four to five percentage points at curb weight, i.e., from 62 to 66% front weight. This adds to the total range of brake balance that vehicles in a single family might deliver in the driver only loading condition. In order for a vehicle to meet consumer expectations, it must be capable of operating under a range of loading conditions from driver only to full GVW. The change in vehicle brake balance that results from this loading condition change will depend upon the amount of weight added and its effect on the location of the vehicle's center of gravity. For example, the FWD example vehicle used for this response undergoes a change in brake efficiency from LLV to GVW of about 15%.

Variations in brake balance among vehicle families include all the sources mentioned above, plus the fact that under FMVSS 105, the manufacturers have had considerable flexibility to establish the nominal brake force distribution (see Appendix 4, Brake Balance Influence on Stopping Distance). The nominal brake force distribution is limited in the degree of rear bias by the unladen vehicle test (the third effectiveness portion of 105), and in the degree of front bias by the laden vehicle tests (first, second, and final effectiveness). Depending upon how the brake designer chooses to strike the compromise between brake balance and stopping distance, a substantial spread in nominal brake force distribution could be encountered.

To summarize, variations in both brake balance and stopping distance result from the inherent nature of the friction process, from the degree of burnish, from the temperature sensitivity of particular friction materials, from manufacturing variations, from the spread of static weight distributions covered by a single vehicle family, from the loading condition of the vehicle, and from the choice of the brake designer as to how the compromise between brake balance and stopping distance shall be made. The magnitude of brake balance variation produced by output changes in a single brake is a function of the nominal distribution of brake forces of the vehicle.

Variability: How Large Is It?

A large collection of test data related to the issue of brake balance variability has been gathered by GM. Much of this data has been gathered on used vehicles and, as was correctly pointed out at the recent GRRF meeting in Dearborn, is not usable to determine the absolute position of the brake balance values relative to the ideal line for new cars. However, GM strongly believes this data is directly applicable to the issue of variability i.e., the scatter between the various measurements of brake balance or efficiency for all vehicles, new or used.

While disregarding the absolute placement of these values relative to ideal brake balance, examining the dispersion among the values measured reveals some interesting observations. Figures 2-6 show brake balance measurements made on various vehicles built for the North American market that were run through a 33 step vehicle assessment schedule that included a wide range of braking conditions. This procedure consisted of several kinds of braking maneuvers including ramp applies, impact applies, single axle locked stops, stops at the limit of adhesion, and low deceleration stops on both wet and dry surfaces. These data are plotted as percent rear brake vs. deceleration. In these tests the brake balance range at a given deceleration value exceeds 10 percentage points in most cases.

Figures 7-11 show GM test results for specific vehicles run through a short 14 step vehicle test procedure that included some of the vehicle conditions of the 33 step test. For each of the vehicles tested to the shorter procedure, the spread in vehicle brake balance, shown as deviation from ideal brake balance, at any given deceleration is of the order of 5-7 percentage points. (The small marks on two of the lines on these figures are F's and L's indicating first and last stop in the test series.)

In Figures 12-17, the GM test results for vehicles run to a NHTSA developed 22 stop procedure are shown as normalized brake efficiency at first axle lock vs deceleration. Here, the brake efficiency varies as much as 60 percentage points, and for most of the vehicles studied exceeds 20 percentage points at most decelerations.

Keep in mind that the results shown in Figures 2-17 are for single vehicles and show that the particular test procedure chosen will affect the measured dispersion. Thus, before a definitive estimate of the range of brake balance to be treated within any harmonized brake standard can be made, a detailed description of the test procedure must be identified.

To examine the minimum range of brake balance that must be recognized within a harmonized brake standard, the data shown in figure 18 must be considered. Here, the brake balance of six identical new FWD vehicles are shown after each was run through a 200 stop burnish per FMVSS 105. These vehicles were loaded to precisely the same weights, and the ramp stops from the GM brake effectiveness schedule were plotted in Figure 18. The GM brake effectiveness test is a seven step procedure that includes two 30 mph (48.3 km/h) ramp stops, and two 60 mph (96.6 km/h) ramp stops where a ramp stop is defined as a brake application rate of 30 pounds (133.4 n) of pedal force per second until first wheel slide. The data shown in figure 18 illustrate that when new vehicles are prepared in precisely the same fashion, and are tested to a precise procedure that GM believes produces consistent brake balance measurements, the minimum variability that FMVSS 135 must recognize is from 8 to 10 percentage points. This is a <u>minimum</u> estimate and may have to be substantially increased if the ultimate test procedure adopted by the agency is significantly different from that used for these tests.

Additional data regarding the variability in brake balance among vehicles of a given family are included in Figures 19-23. These data are for groups of vehicles tested from customer service at various mileages, and show a broad range of vehicle brake efficiency. These variations are thought to be due to the wide range of work history that general drivers may develop in their personal usage of vehicles, in addition to any differences that may have existed between the vehicles at the time of manufacture.

This data was gathered using GM's RTP (road transducer pad) facility, and is generally indicative of brake balance variability in vehicles built to comply with FMVSS 105 that are in the hands of the customers.

The most complete summary of the range of vehicle brake balance in the hands of the customer in the U.S. market is given in Figure 24. Here the brake balance of 549 vehicles in the used condition are shown. This data shows that a broad range of vehicle brake balance exists in the hands of drivers today.

Since the U.S. automotive population includes a range of brake efficiency of from 60% rear axle limited to 60% front axle limited, or a total span of 80 percentage points, GM views it as unreasonable to propose a harmonized brake standard calling for a span of only a few percentage points. The present US standard, and ECE 13 both allow substantially larger ranges in vehicle brake balance. (See Appendix 5, Brake Balance Window in FMVSS 135.) The present form of FMVSS 135 would be unlikely to gain acceptance in the international community once the standard's impact has been assessed.

It should also be pointed out that while the GM test data on brake balance variability is large, it is based primarily on vehicles built to comply with FMVSS 105 and equipped with friction materials suitable for use in the domestic market. The variation in output for brake systems and friction materials suitable for the European or other markets is not well studied, although we do have some European laboratory tests of friction material that shows a broad range of variability (figure 24A).

As noted earlier, the use of semi-metallic friction materials in front disc brakes has been the direct result of the fade and recovery limits of FMVSS 105, while asbestos friction materials dominate the drum brake applications. The public concerns regarding the use of asbestos friction materials have generally suspended the application of these materials to vehicle braking systems where viable substitutes are available. The friction material industry continues to study various alternatives to asbestos, with many attempts to develop compounds based on graphite, aramid, and Kevlar fibers currently underway. The variations in brake output to be expected with these materials are unknown at this time.

Based on the data reviewed in this section, provision for a range in vehicle brake balance of at least 10 percentage points must be made when considering a physical test under carefully controlled conditions. This estimate is applied to the requirements of an international brake standard with reluctance, since the precise test procedure and many of the vehicles and brake friction materials ultimately to be covered by this standard have not been studied extensively. This estimate is based on the study of vehicles at one particular stage of burnish, and subjected to a minimum dispersion test procedure. Deviations from this practice would only increase the range of variability that must be accommodated.

Variability, How It Affects Stopping Distance

We shall now examine the impact of a range of 10 percentage points in vehicle brake balance on stopping distance. To treat this aspect of the variability question, we can assume our example FWD vehicle is operating on a constant 0.80 tire to road coefficient. Likewise, since FMVSS 135 calls for nominally front biased vehicles, we can work with the front axle limited equations for deceleration and identify the impact of a 10 percentage point range in vehicle brake balance on stopping distance.

To begin, assume first that adhesion utilization certification will be handled by the ECE R13 approach. This version of the example FWD vehicle has a nominal brake balance such that it is very close to the ideal in the unladen condition, and front axle limited in the laden condition. Recall from Appendix 2, Derivation of Brake Balance Representations, that this version of the example FWD vehicle has a nominal rear brake fraction of 0.17 at the limit of adhesion on a 0.80 tire to road coefficient. With a range of 10 percentage points in vehicle brake balance, this suggests the family of vehicles would require a total range in rear brake fraction of 0.12 to 0.22. Let us consider each end of this range separately.

When the rear brake fraction in 0.12, the vehicle is front axle limited under all loading conditions, and the limiting condition for stopping distance is the laden vehicle. In the laden condition, the front axle limited deceleration is given by equation 15 of Appendix 2, Derivation of Brake Balance Representations,

$$A = (ub)/\{[(a+b)(1-R_r)]-(uh)\} \qquad (1)$$

where all the symbols are defined as before. Substituting into (1) the appropriate values, we find that the front axle limited deceleration is 0.628g (20.2 ft/s^2, 6.2 m/s^2). This analytical result is shown on the laden example vehicle fishbone diagram in Figure 25. This deceleration rate translates to a 100 km/hr (62.1 mph) stopping distance, assuming the 0.60 second reaction time, of 71.3 m (234 feet). Again, this is a theoretical minimum value. This may be compared to the value obtained in the Appendix dealing with burnished brake system performance for this same version of the FWD example vehicle in the same loading condition where the theoretical minimum stopping distance of 67 m

(219.8 feet) was calculated. Thus, accommodating a minimum estimate of variability in vehicle brake balance calls for an increase in stopping distance of 4.3 m (14.2 feet) or 6.5%.

When the rear brake fraction is 0.22, the example FWD vehicle is rear axle limited in the lightly loaded condition, and front axle limited in the laden condition. Again recalling from the response section dealing with the derivation of brake balance representations that the rear axle limited deceleration is given by equation 14 of Appendix 2,

$$A = (ua)/\{[(a+b)(R_r)]+(uh)\} \qquad (2)$$

where the symbols carry the same definition as before. Substituting the appropriate values into equation (2) gives a rear axle limited deceleration in the unladen condition of 0.70g (22.5 ft/s^2, 6.9 m/s^2). Under the same assumptions as before, this translates into a theoretical minimum stopping distance of 64.5 m (211.6 feet) from a vehicle speed of 100 km/h (62.1 mph). For this same vehicle configuration and loading condition with burnished brakes, a minimum stopping distance of 58.1 m (190.6 feet) was obtained earlier. Thus an increase of 6.4 m (21 feet) or 11% in theoretical minimum stopping distance is required to accommodate the minimum estimate of real world variation in vehicle brake balance.

When the adhesion utilization requirement is to be verified using a physical test, the nominal FWD example vehicle will have a rear fraction of 0.12. This means the range in vehicle brake balance will be from 0.07 to 0.17 fraction rear. Since the 0.07 value is the dominant extreme in terms of stopping distance, we can focus on this single value. With a rear brake fraction of 0.07, the example vehicle is front axle limited under all loading conditions, and equation (1) applies. Considering the laden vehicle condition, substituting appropriate values into (1) yields a front axle limited deceleration of 0.59g (19.0 ft/s^2, 5.8 m/s^2). This result is confirmed by considering the laden example FWD vehicle fishbone diagram in Figure 26. Under the same assumptions as before, this translates into a theoretical minimum stopping distance of 75 m (246 feet). This may be compared to the value of 71.8 m (235.4 feet) obtained without accounting for minimum estimate variability in vehicle brake balance. For this particular vehicle configuration, the stopping distance increase attributable to the inclusion of a physical test for adhesion utilization is 3.2 m (10.6 feet) or 4.5%.

In summary, stopping distances are increased when real world brake balance variability is properly recognized. The magnitude of the increase will vary depending upon the agency's decision regarding verification of brake balance requirements. Until this key issue is resolved, neither a final estimate of the range of variability to be recognized nor the impact on vehicle stopping distance can be made.

Consider for a moment the requirements already contained in draft proposal R.88. Under this proposal for a harmonized brake standard, the stopping distance allowed is 77m (252.6 feet) from 100 km/h (62.1 mph). If adhesion utilization is to be certified by design calculation as is the present practice in ECE R13, then the theoretical minimum stopping distance figure of 71.3 m (234 feet) for our example FWD vehicle, after accounting for variability in brake balance, represents a total pass margin of 7.4%. From this pass margin must be subtracted any additional stopping distance due to side to side torque or dynamic weight differences, driver skill, and tire to road coefficient differences on any of the four corners.

If adhesion utilization is to be certified by specific vehicle test, then the R.88 stopping distance of 77 m (252.6 feet) represents only a 2.6% pass margin over the theoretical minimum requirement of 75 m (246 feet). Again, from this margin must be subtracted any additional stopping distance due to any other source of variation. This margin, after further corrections are made, is unacceptably small. Even given the stopping distances of R.88, it seems unlikely that the addition of a specific vehicle test for adhesion utilization would allow manufacturers sufficient margin to reduce the probability of noncompliance to acceptable levels.

January 13, 1986

USG 2456

EXAMP FWD VEHICLE AT NOMINAL AND ±30% FRONT

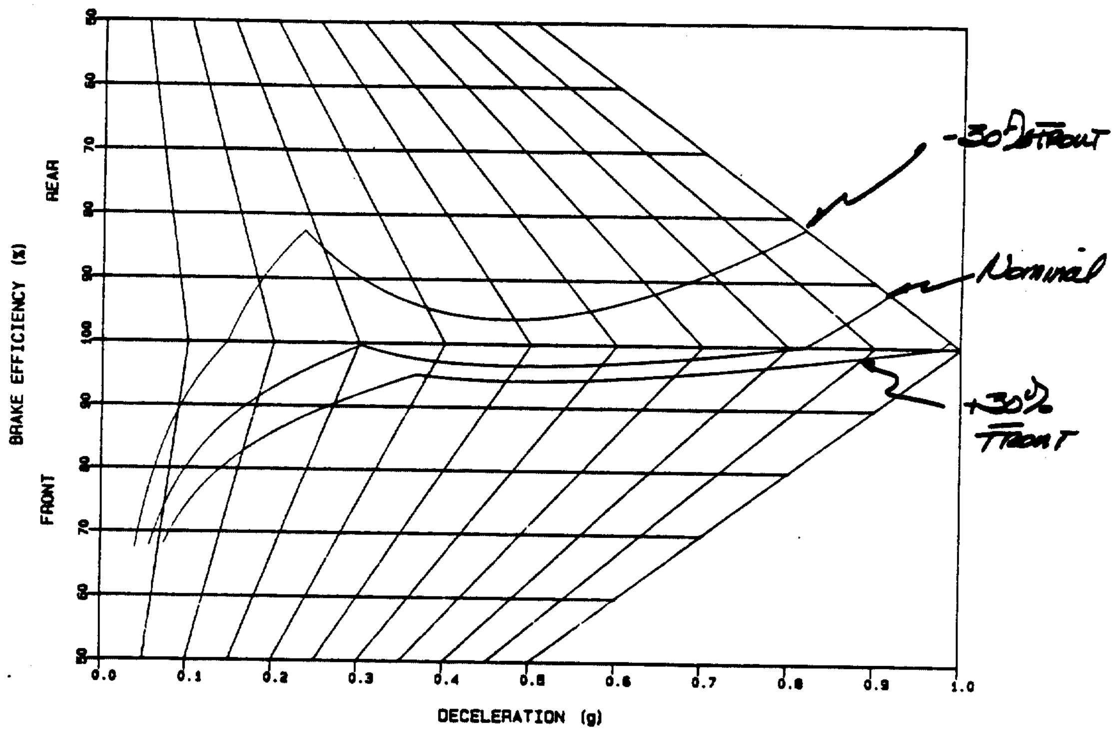


Figure 1

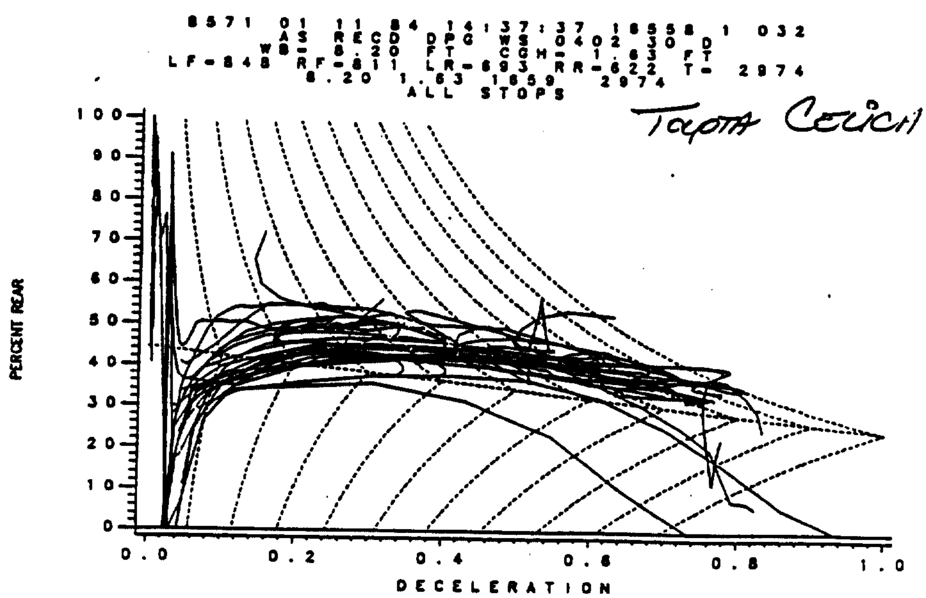


Figure 2

USG 2456

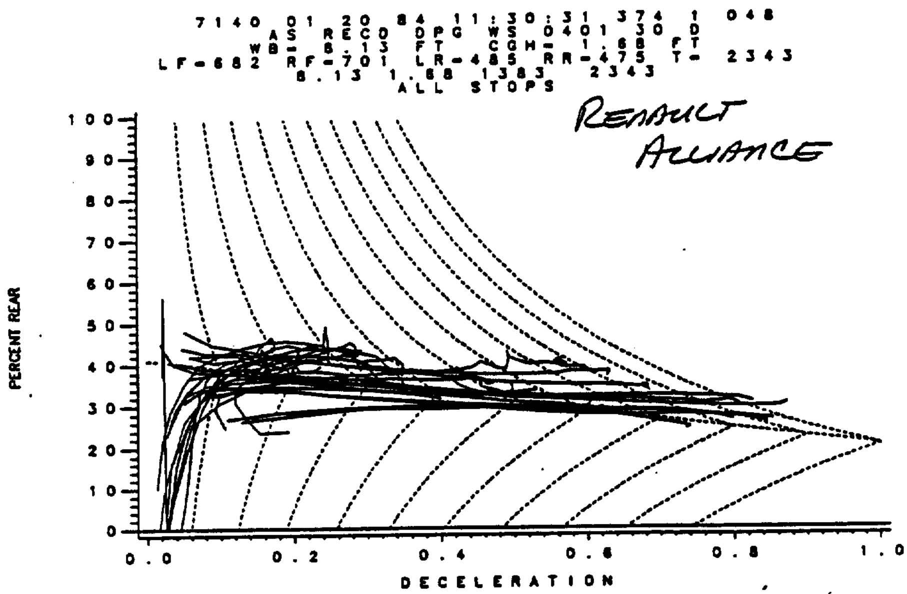


Figure 3

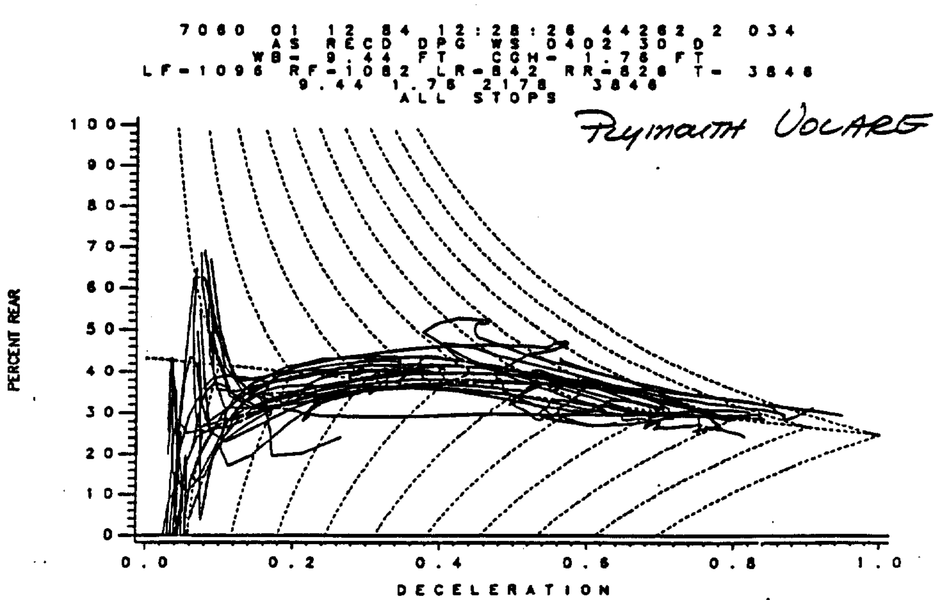


Figure 4

USG 2456

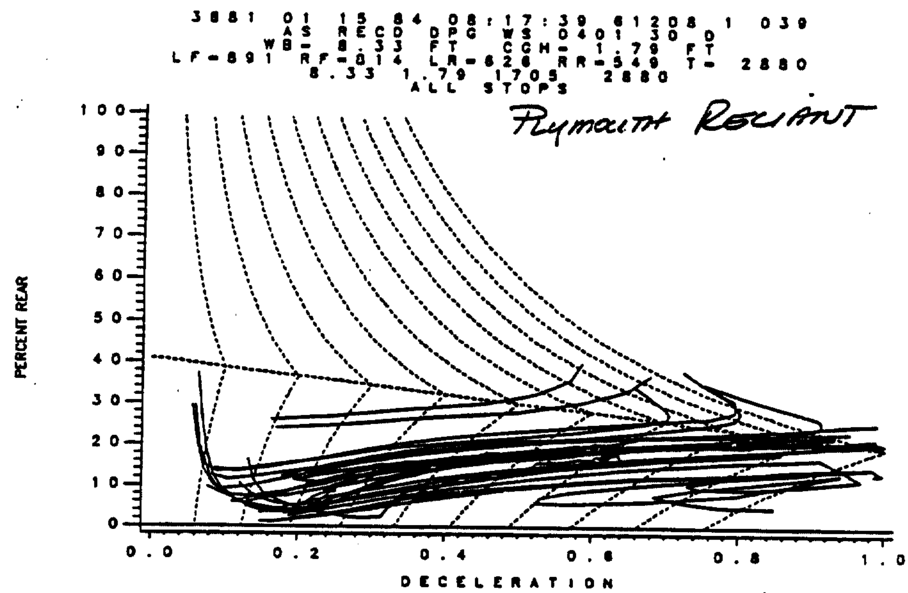


Figure 5

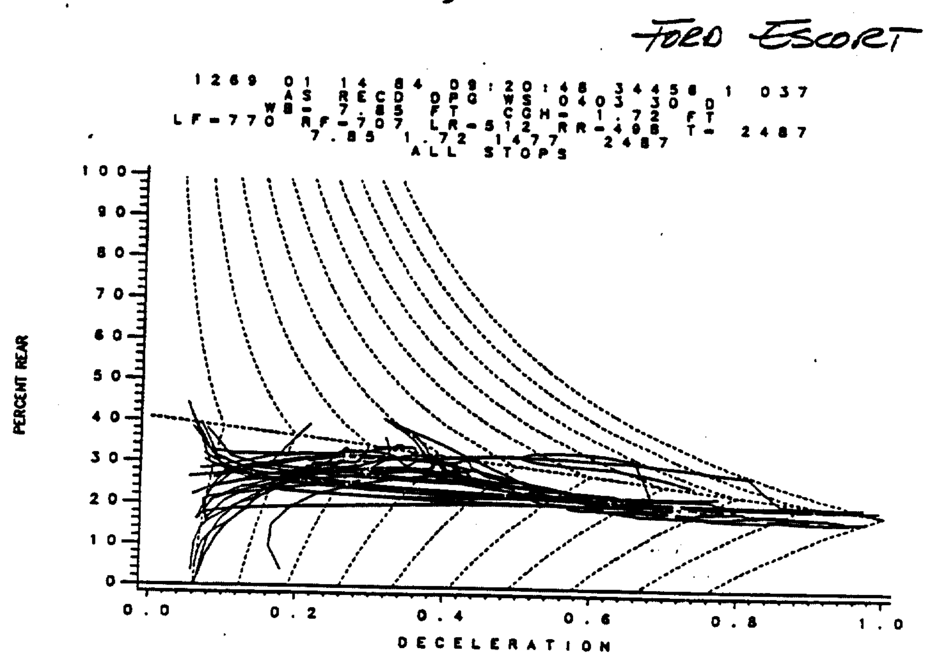


Figure 6

USG 2456

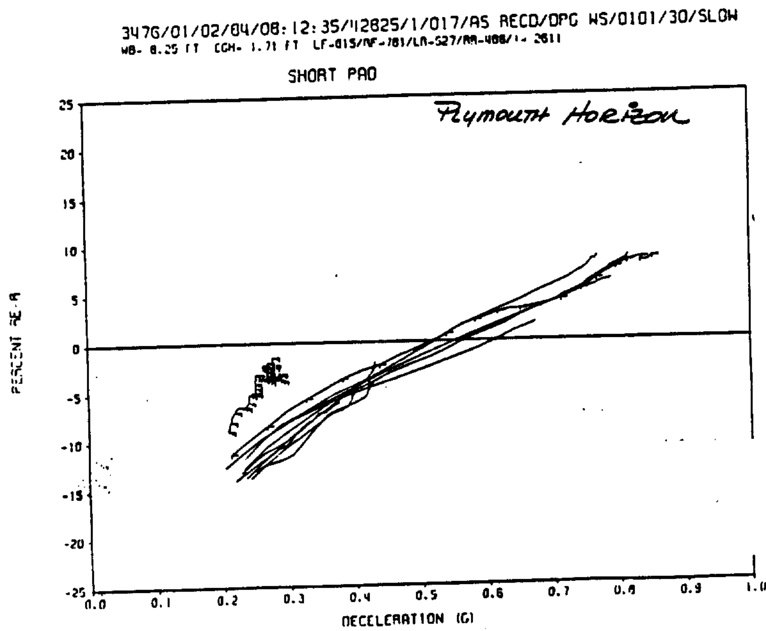


Figure 7

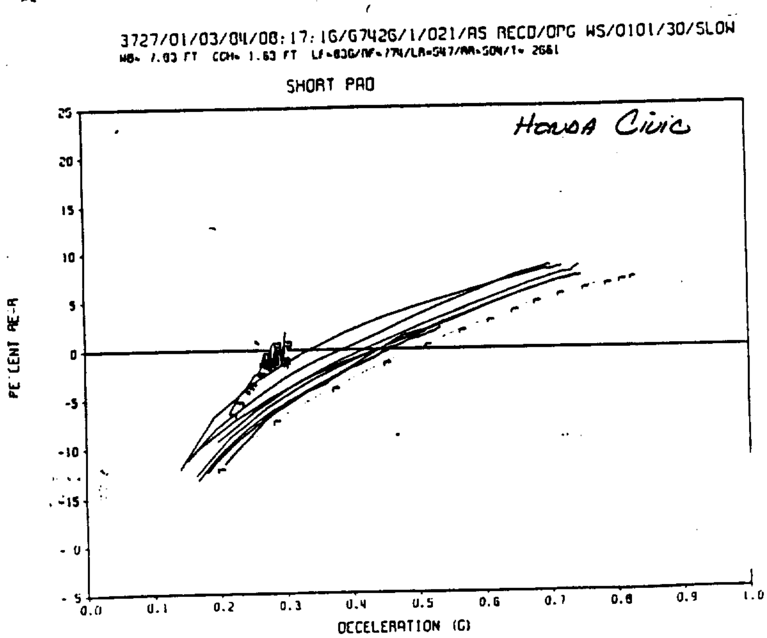


Figure 8

USG 2456

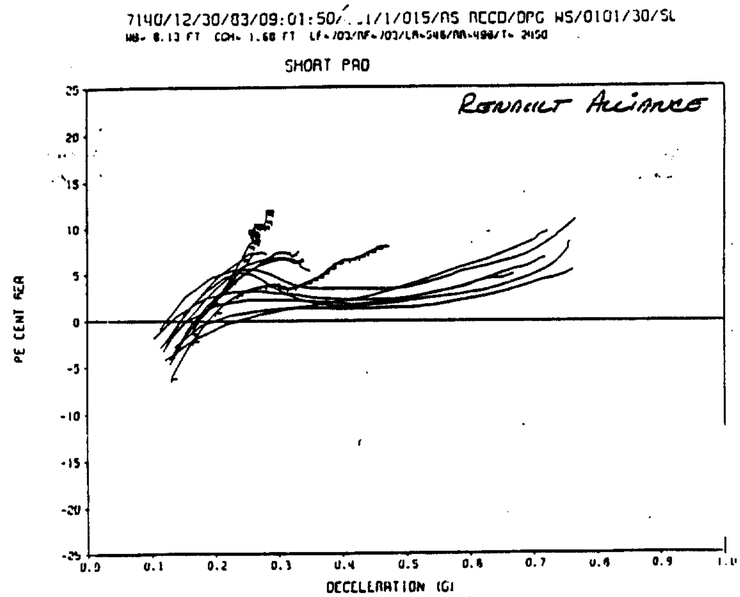


Figure 9

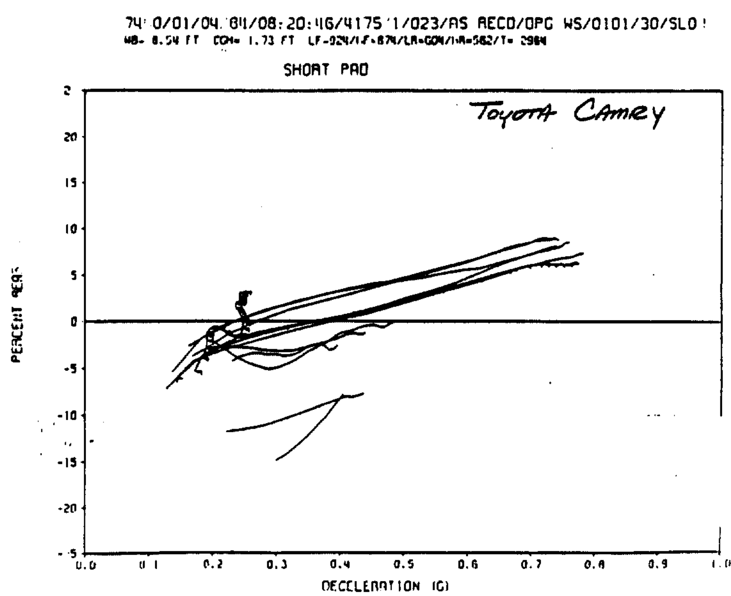


Figure 10

USG 2456

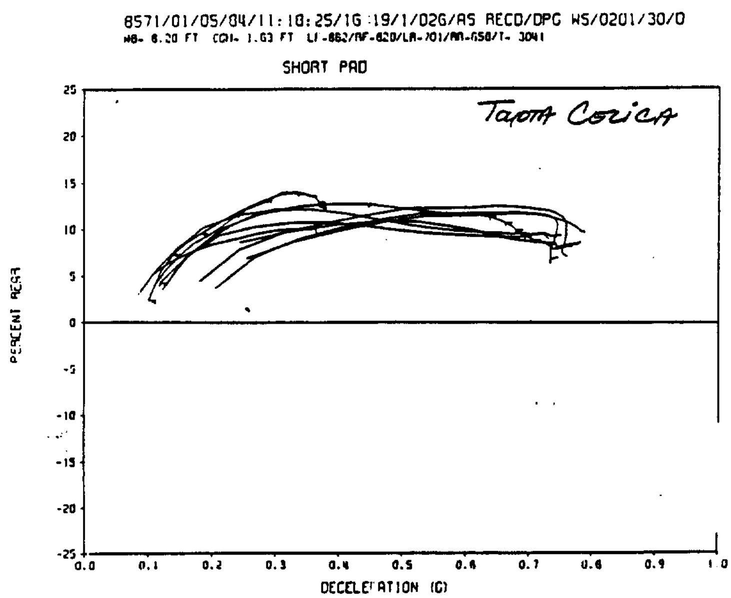


Figure 11

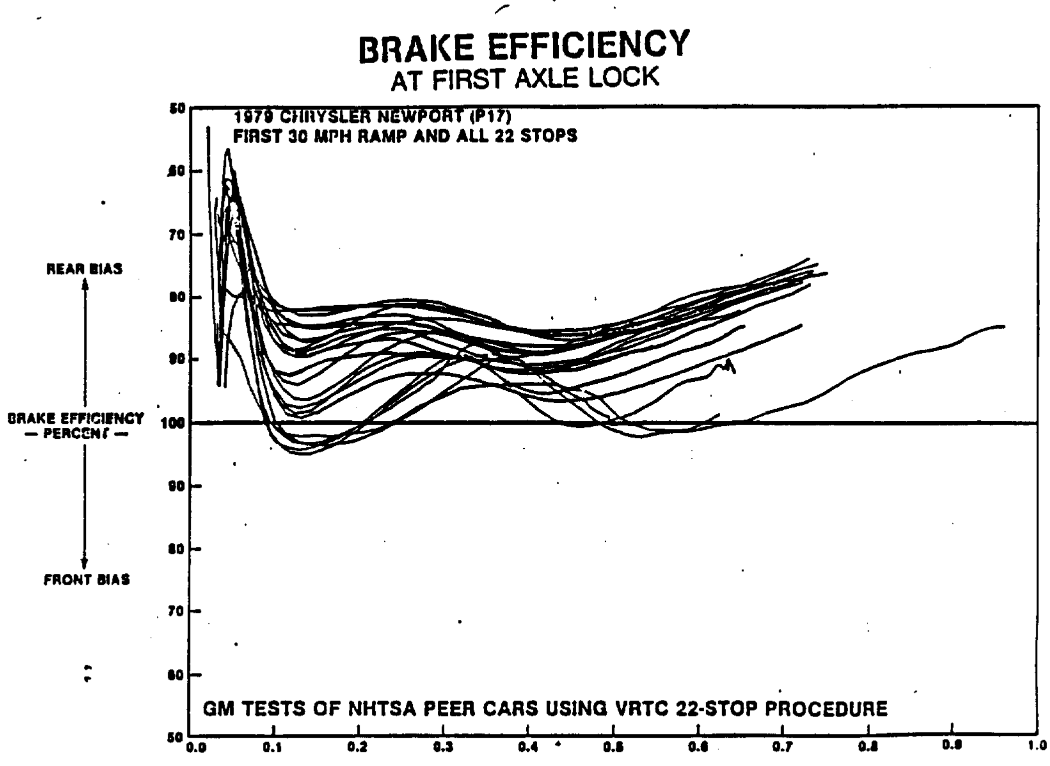


Figure 12

USG 2456

BRAKE EFFICIENCY
AT FIRST AXLE LOCK

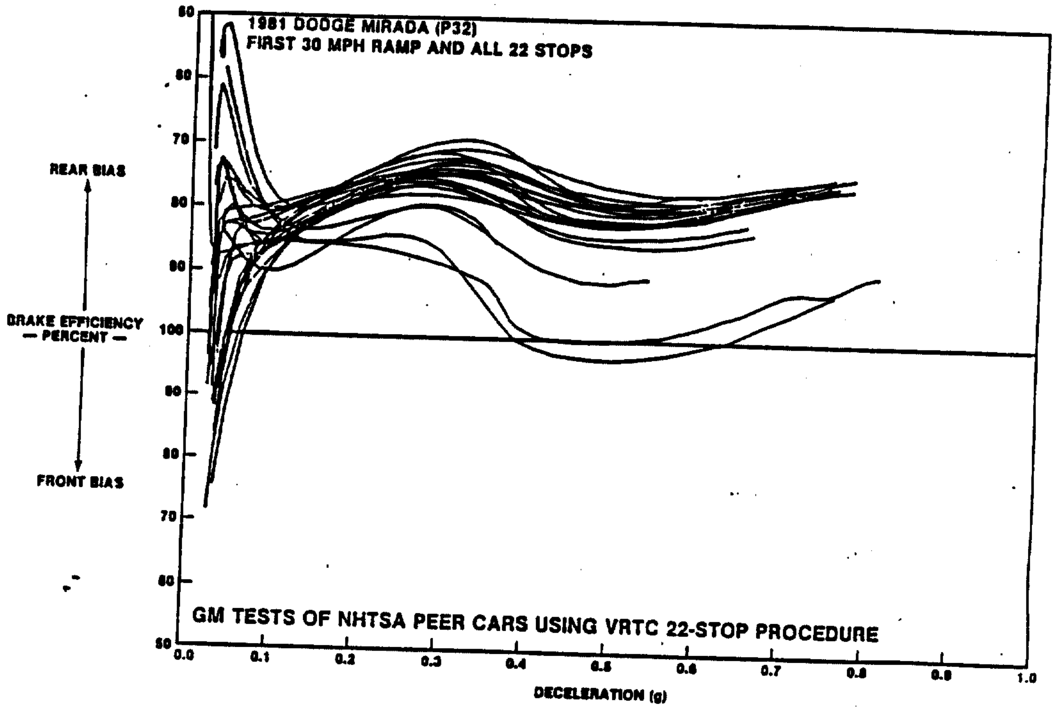


Figure 13

BRAKE EFFICIENCY
AT FIRST AXLE LOCK

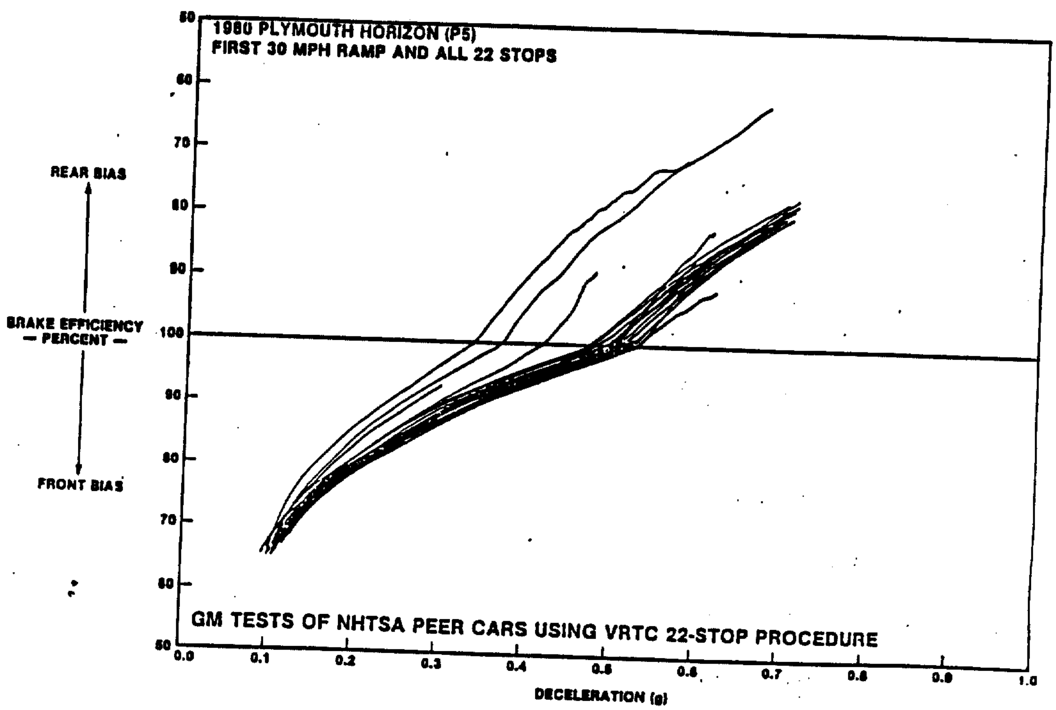


Figure 14

USG 2456

BRAKE EFFICIENCY
AT FIRST AXLE LOCK

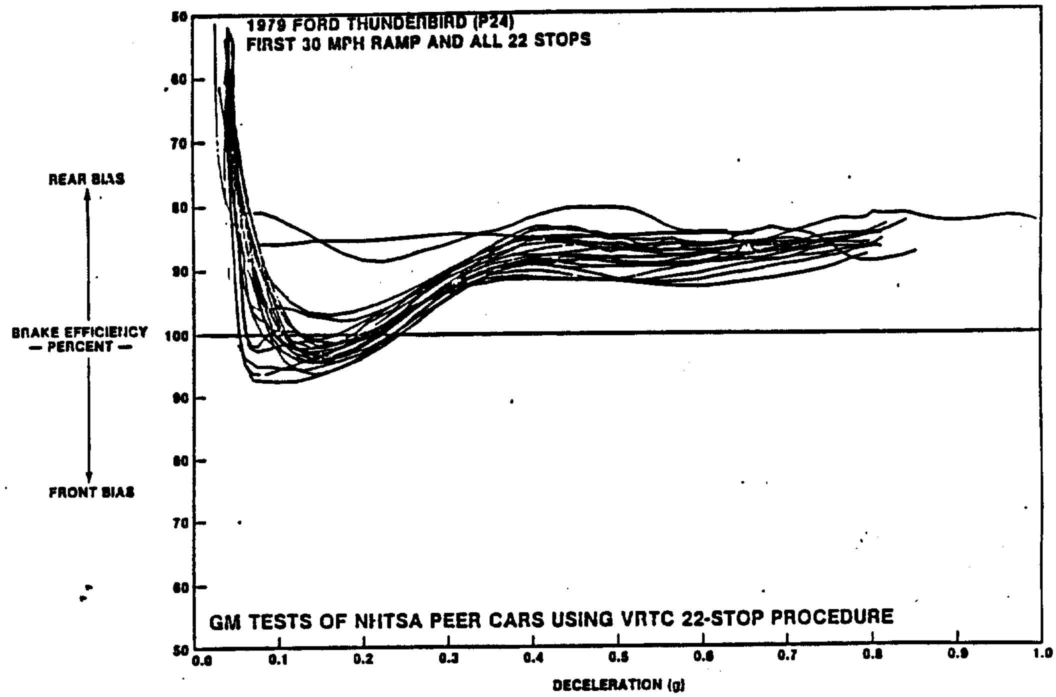


Figure 15

BRAKE EFFICIENCY
AT FIRST AXLE LOCK

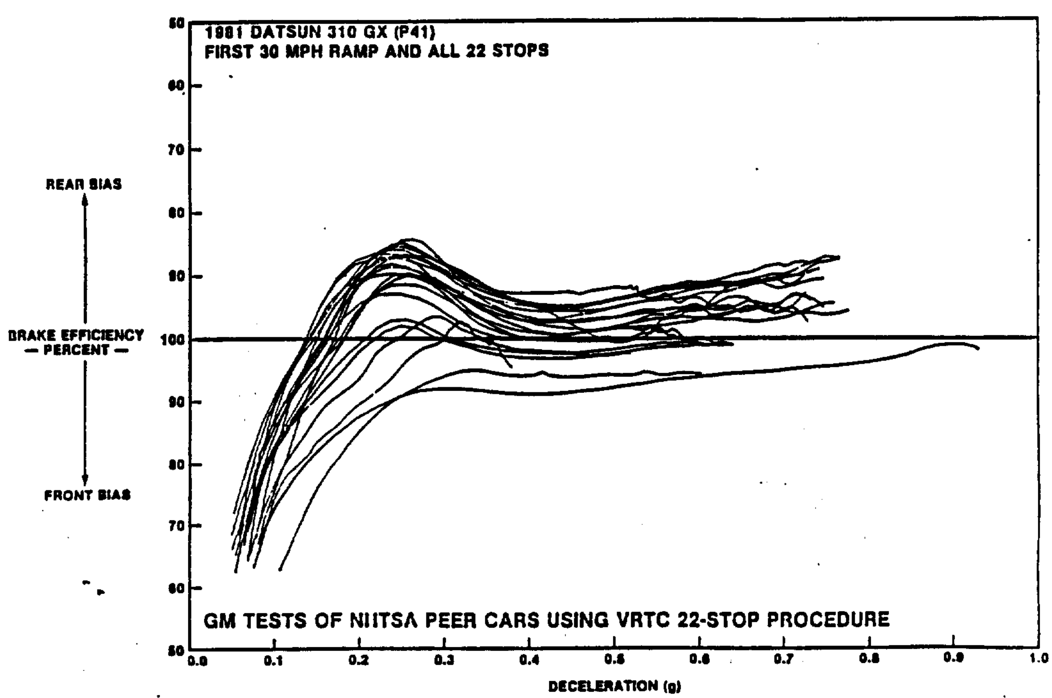


Figure 16

USG 2456

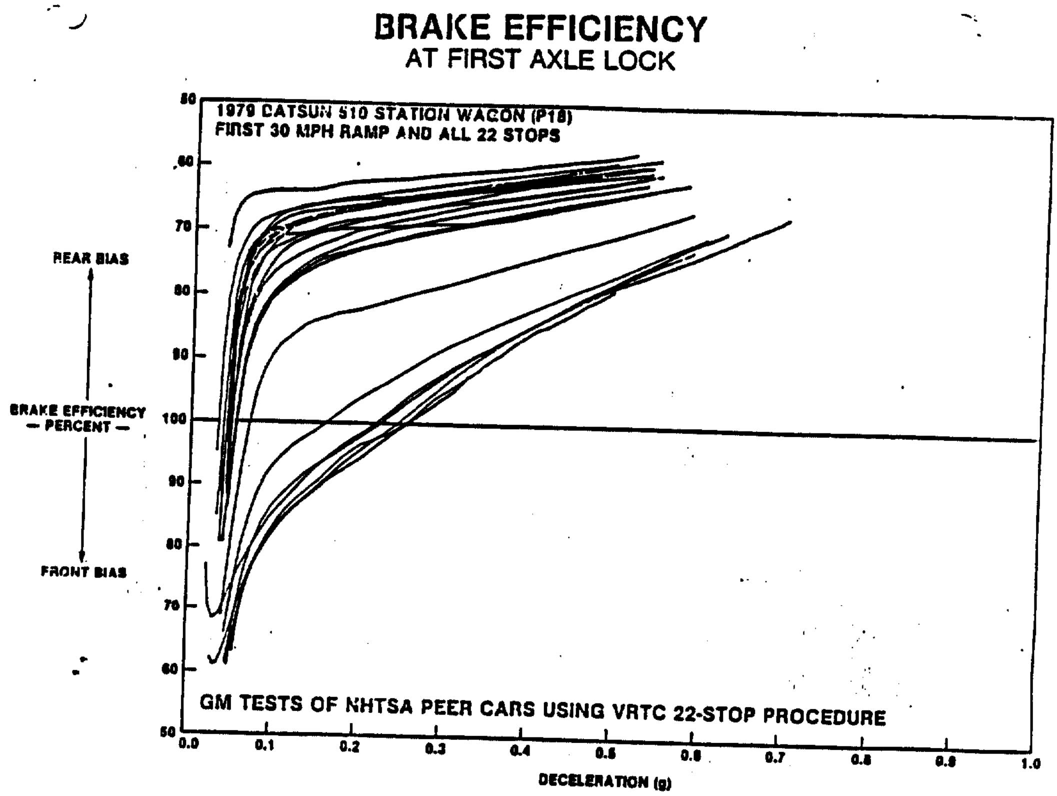


Figure 17

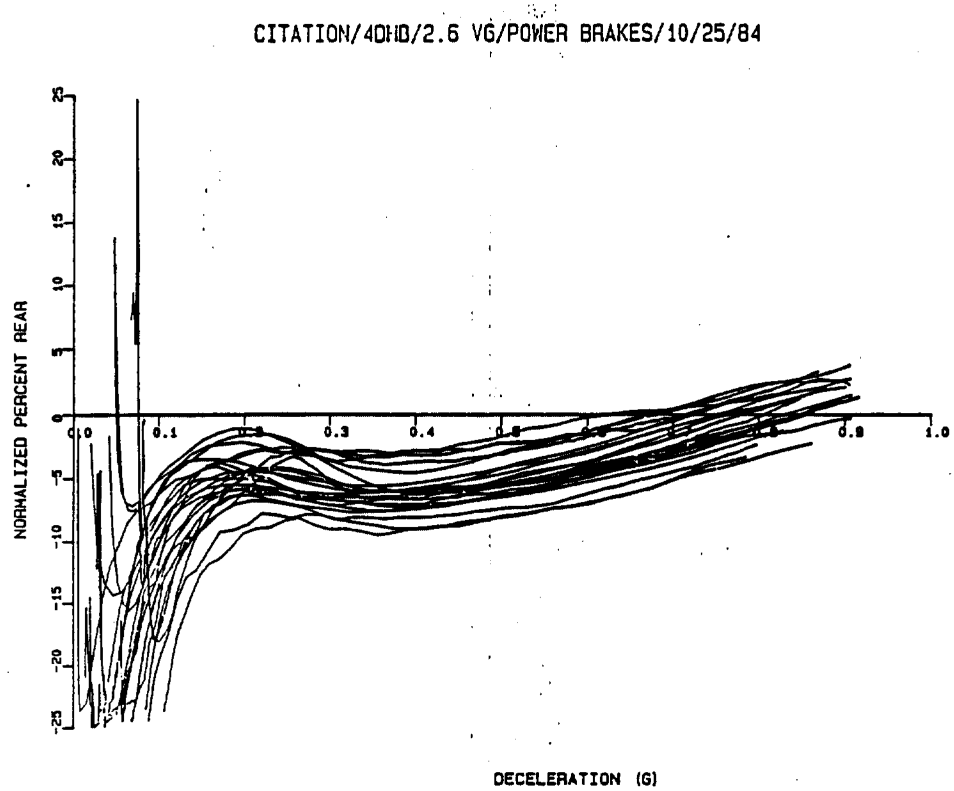


Figure 18

USG 2456

BRAKE EFFICIENCY
AT FIRST AXLE LOCK

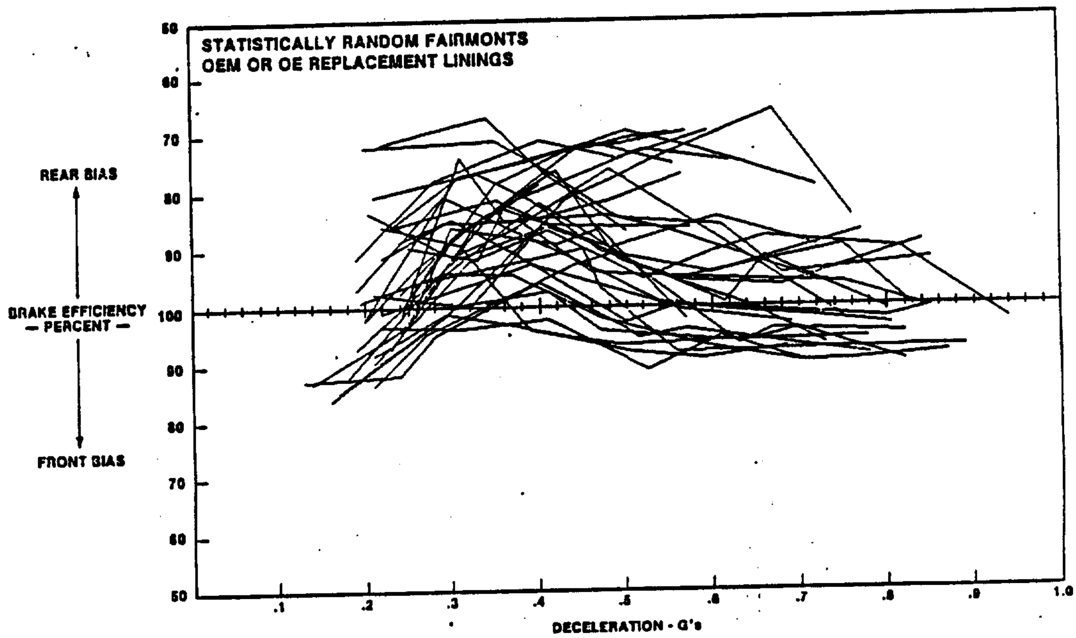


Figure 19

BRAKE EFFICIENCY
AT FIRST AXLE LOCK

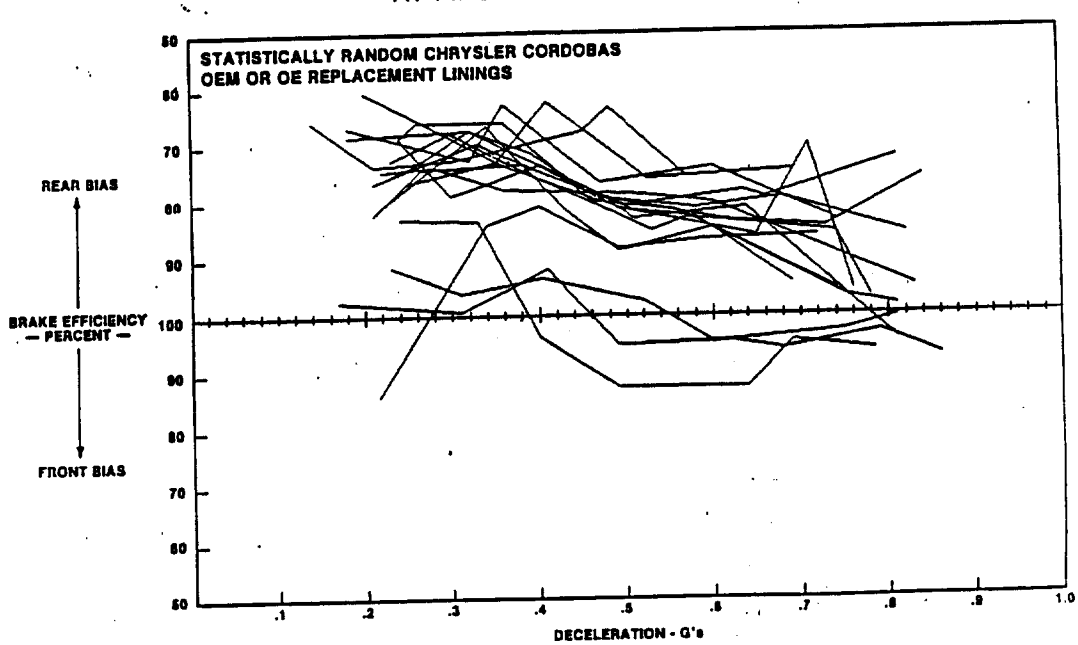


Figure 20

USG 2456

BRAKE EFFICIENCY
AT FIRST AXLE LOCK

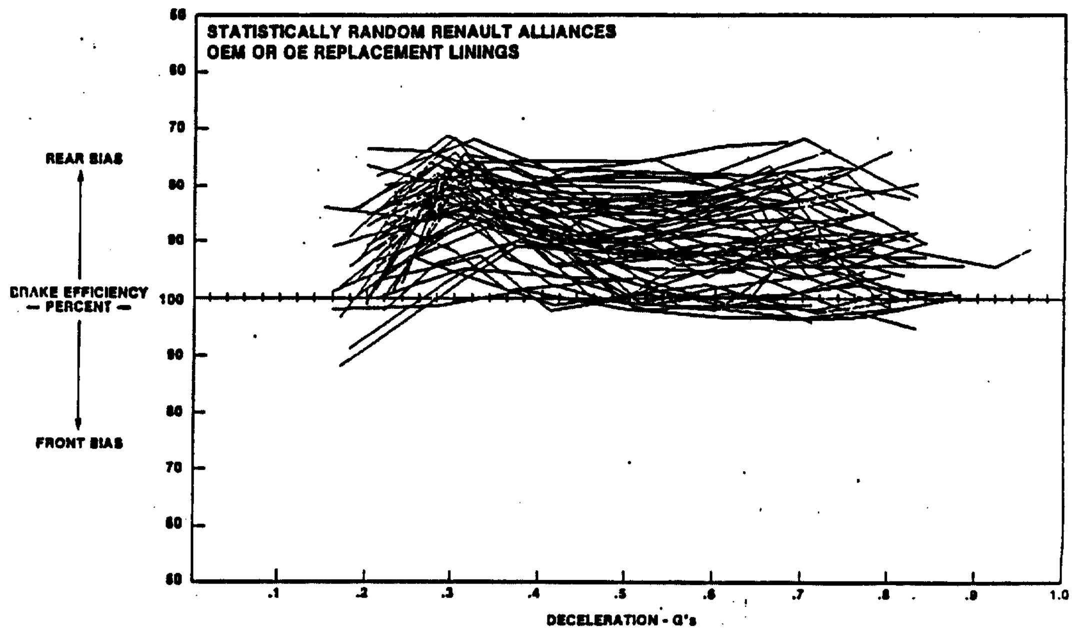


Figure 21

BRAKE EFFICIENCY
AT FIRST AXLE LOCK

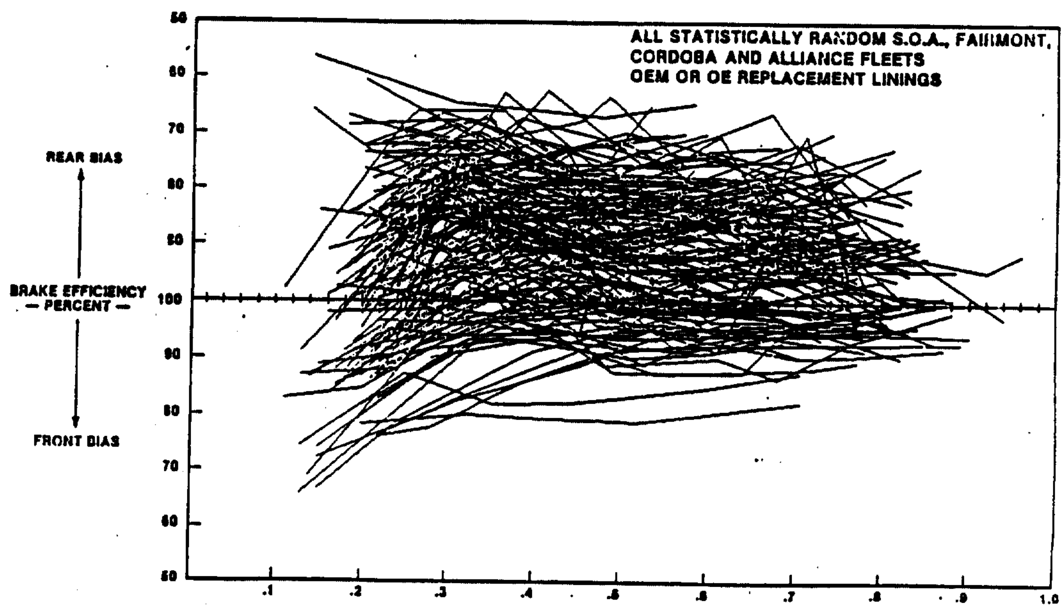


Figure 22

USG 2456

BRAKE EFFICIENCY
AT FIRST AXLE LOCK

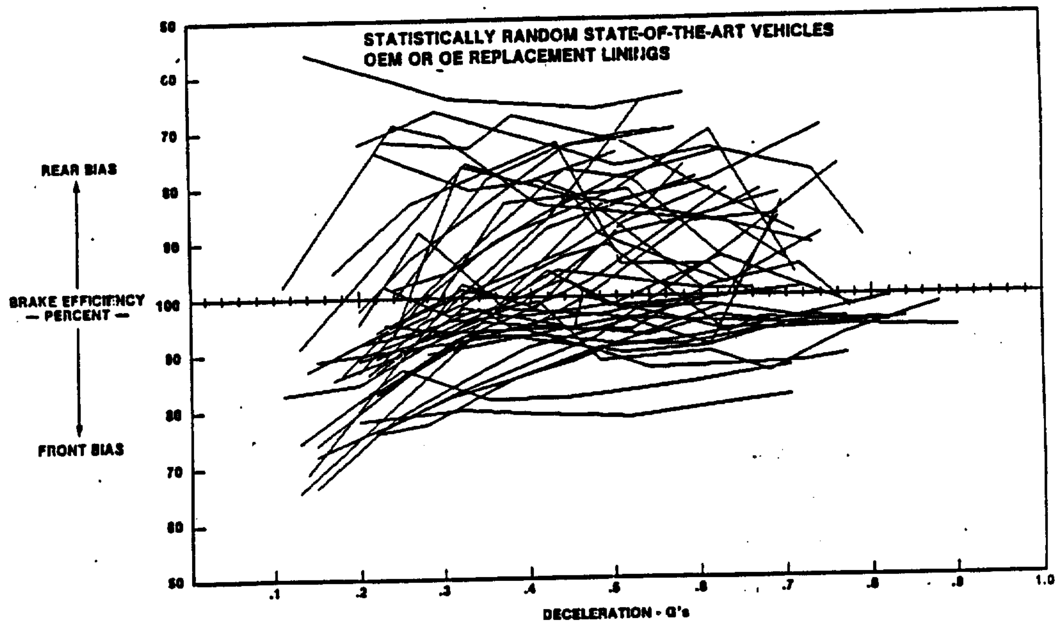


Figure 23

BRAKE EFFICIENCY
AT FIRST AXLE LOCK

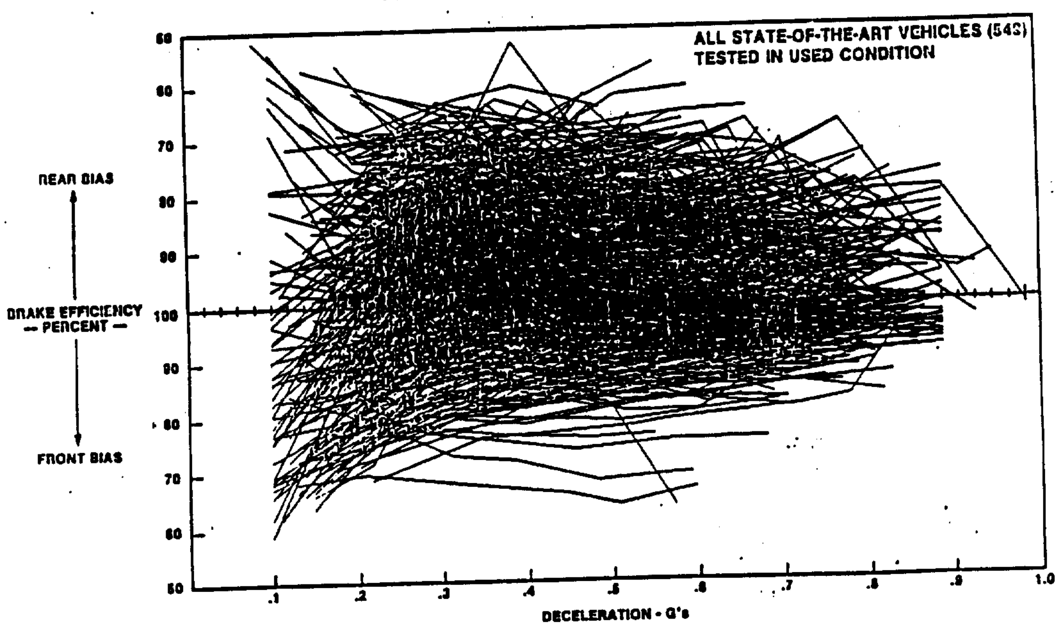


Figure 24

USG 2456

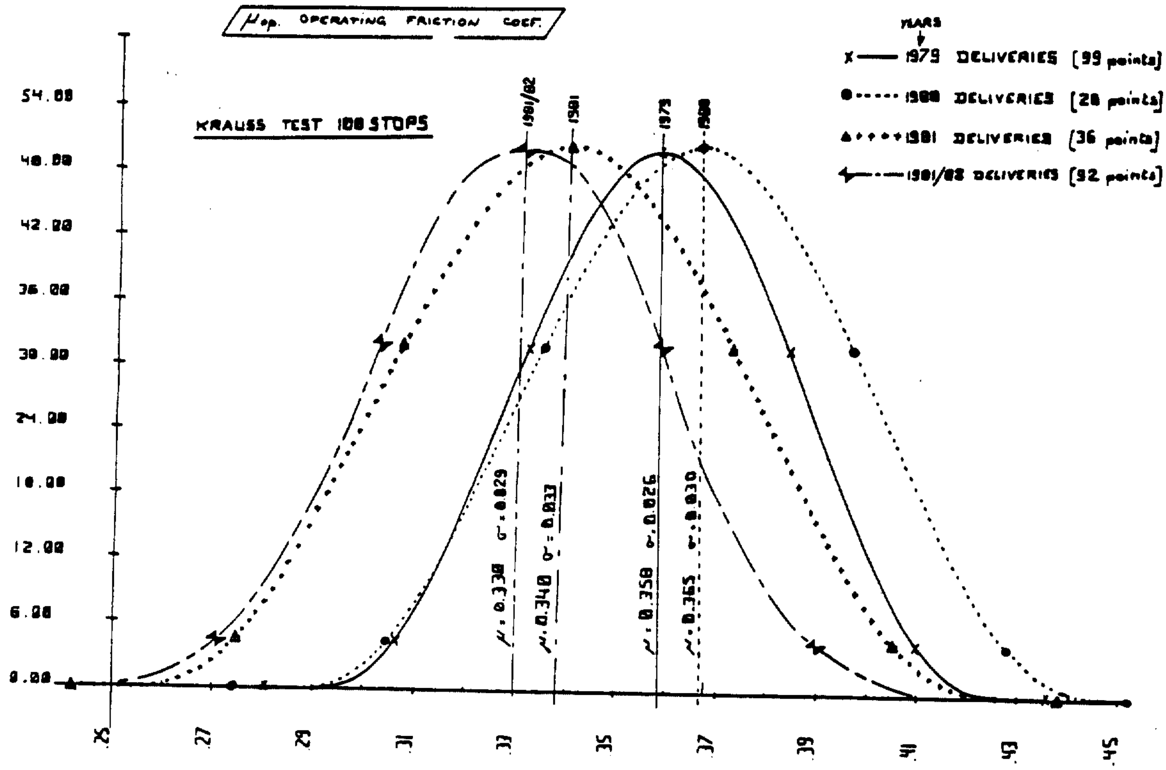


Figure 24A

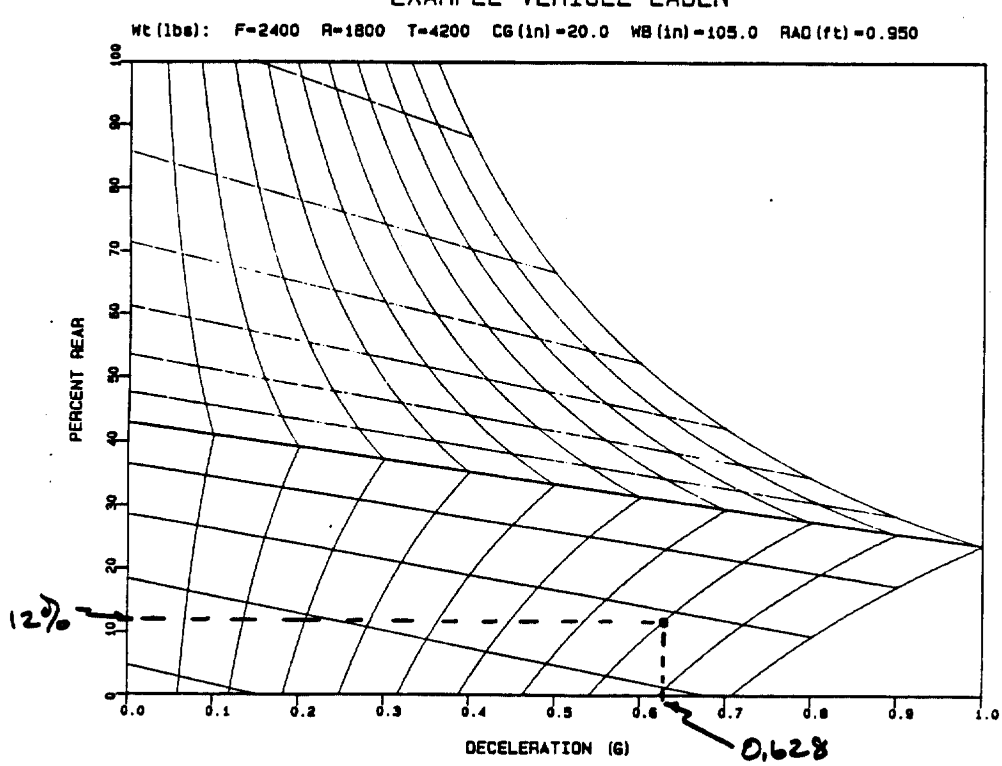


Figure 25

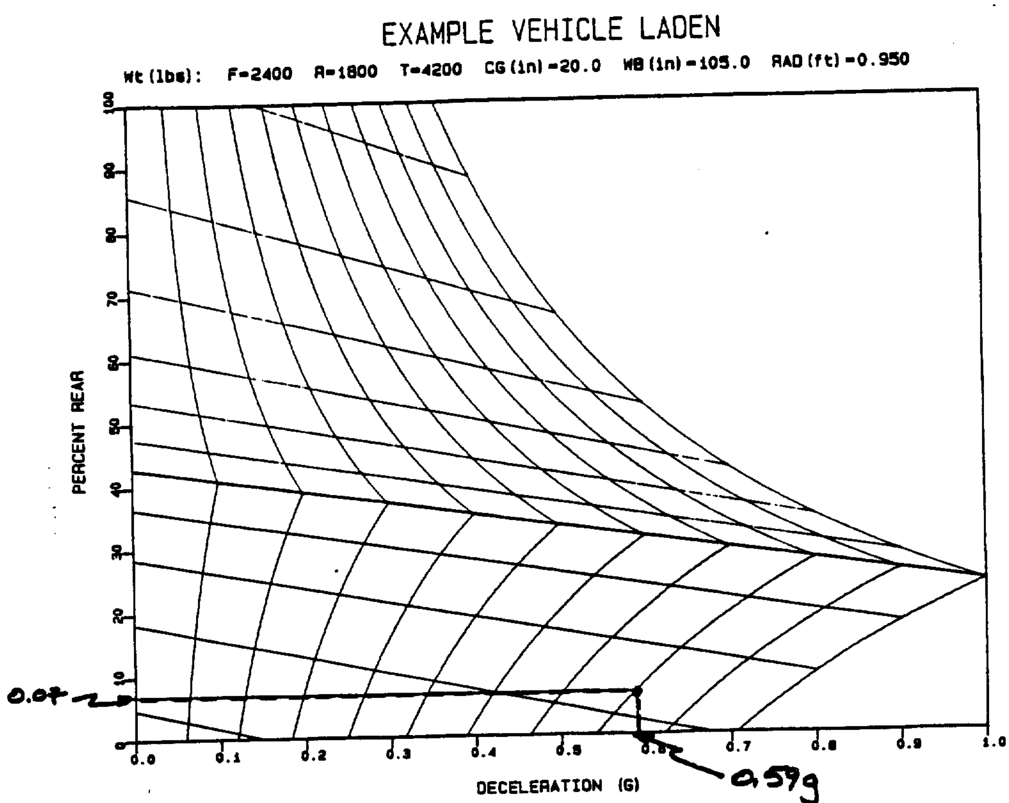

EXAMPLE VEHICLE LADEN
Wt (lbs): F=2400 R=1800 T=4200 CG (in) =20.0 WB (in) =105.0 RAD (ft) =0.950
PERCENT REAR
DECELERATION (G)
0.07
0.59g

Figure 26

ADHESION UTILIZATION ASSESSMENT TESTS

OBJECTIVE

This appendix reviews the results of GM's testing comparing three methods of measuring vehicle brake balance: the single axle procedure as prescribed in FMVSS 135, torque wheels, and the Road Transducer Pad (RTP) .

CONCLUSIONS

1. The single axle test procedure for measuring vehicle brake balance is lengthy and prone to error.

2. The torque wheel test method will likely be too complex and expensive for routine use as a compliance or type approval technique. While providing the most direct measurement of brake performance, it requires substantial instrumentation, investment in a large inventory of torque wheels, and lengthy set-up time.

3. The RTP appears to be an appropriate compliance or type approval tool because the test is relatively short, requires no vehicle modifications, and directly measures all forces delivered to the road, regardless of source.

4. The use of the "Swedish test" (a simple skid check), or the single axle procedure, does not provide measurements of vehicle brake balance over a range of decelerations. Consequently, either of these techniques would not meet the original intent of the European ECE R13, Annex 10; that is, to account for brake behavior on a range of tire to road coefficients.

5- The inclusion of a vehicle test for brake balance increases the stopping distance penalty that is associated with requiring front axle limited brake balance, as explained in Appendix 4, Brake Balance Influence on Stopping Distance.

6- The calculation approach to brake balance regulation that is currently part of ECE R13 would avoid or diminish many of the problems associated with establishing a vehicle test for brake balance.

RECOMMENDATIONS

1- Adhesion utilization certification using the calculation procedure of ECE R13 should be adopted in FMVSS 135. This action would substantially increase the opportunity for harmonization, reduce the stopping distance penalty associated with requiring front axle limited brake balance.

2- The agency should carefully consider the consequences of requiring a vehicle test for brake balance. The extensive testing that should be done to validate a method and procedure could delay a harmonized brake standard by several years.

DISCUSSION

Introduction

Adhesion utilization or vehicle brake balance is a very important part of the proposed harmonized brake standard FMVSS 135. Notice 1 proposes a vehicle test procedure to measure the brake balance. GM has conducted a series of vehicle tests in which the brake balance predicted from the proposed test (which is referred to in this response as the "single axle procedure") is compared to torque wheels and the RTP in order to assess the technical accuracy and reliability of the proposed test procedure, and the correlation between procedures.

Both front and rear wheel drive vehicles were studied in this program, with each being a six passenger vehicle built for the North American market in 1985. These two vehicles were equipped with torque wheels, line pressure transducers, wheel speed and wheel revolution counters, vehicle decelerometer, and pedal force transducers. A high speed digital data acquisition system was used to gather and store the data generated during brake applications.

Vehicle brake balance was determined by each of the three methods in both the unburnished and burnished conditions, each at LLV and GVW. The specific test sequences that were followed, and the test results, are reviewed below.

The RWD vehicle was tested by first rebuilding the vehicle brake system to include all new hardware except proportioning valves and brake pipes. After rebuild, the vehicle was loaded to GVW, and run through the FMVSS 135 pre-burnish effectiveness, burnish, and burnished effectiveness tests. A total of 86 burnish stops were accumulated. Pre-snubs called for by the single axle procedure were followed by the fronts and rears only portions of the single axle procedure. Vehicle coast downs in neutral and in gear were followed by four ramp applies to first wheel slide with the vehicle at GVW to establish the torque wheel brake balance of the vehicle in the laden condition. An RTP test at GVW followed. The vehicle was then unloaded and four more ramp applies to first wheel slide were made to establish unladen torque wheel brake balance. These four stops were followed by an RTP test of the vehicle in the unladen condition.

The RWD vehicle was then rebuilt with new friction material, rotors, and drums, and reloaded to GVW. Torque wheel measurements of brake balance with green linings at GVW were developed by running the single axle procedure pre-snubs, fronts only, and rears only tests followed by four ramp applies to first wheel slide. These four stops were followed by a green lining RTP test. The vehicle was then unloaded to the LLV condition, and single axle procedure coast downs at LLV were followed by four ramp applies to first wheel slide to establish the torque wheel measurement of LLV brake balance with green linings. These stops were followed by the LLV RTP test. (Note that the number of stops included in this "green" condition series necessarily affects the lining conditioning and thus affects the absolute comparison of methods.)

A similar test procedure was followed for the FWD vehicle in both the green and burnished lining tests. These tests ultimately produced virtually simultaneous measurements of vehicle brake balance by the torque wheels and the RTP.

For purposes of the GRRF visit to GM's Milford Proving Grounds during October of 1985, the results of this testing were plotted in the adhesion utilization format of ECE R13. For purposes of this response, the data has been left in the same format.

Data Review

Consider first the green brake balance of the RWD vehicle in the unladen condition. The projected vehicle brake balance based on the data gathered using the single axle procedure is shown in figure 1. This may be compared to the torque wheel brake balance measurements made during each of the four ramp applies with each individual stop shown separately in figures 2-5. For this lining and vehicle loading condition, the single axle method predicts the vehicle is more front biased at low decelerations than do any of the four torque wheel stops. A similar observation can be made by reviewing the GVW test for the green lining condition of the RWD vehicle. The single axle projection for this vehicle configuration is shown in figure 6, and the individual ramp stops are shown in figures 7-10.

The burnished lining tests of this same vehicle in the LLV loading condition are shown in figures 11-15. The single axle projection of vehicle brake balance is shown in figure 11 with the four ramp stops shown individually in figures 12-15. Again, the single axle procedure tends to show this vehicle configuration to be more front biased than the ramp stops of actual wheel torques would suggest. For the burnished lining test of the RWD vehicle in the GVW loading condition, the single axle projection shown in figure 16 predicts a higher degree of front axle utilization that any of the four torque wheel ramp stops shown in figures 17-20.

For the front wheel drive vehicle with green linings, the LLV loading condition brake balance projected from the single axle method shown in figure 21 shows this vehicle to be slightly rear axle limited at about 0.30g (9.7 ft/s^2, 2.9 m/s^2) deceleration. The four ramp stops with torque wheels shown in figures 22-25 show the vehicle ideally balanced or front axle limited at this same deceleration. In the GVW loading condition with green linings, the FWD vehicle produces a single axle projection of vehicle brake balance, shown in figure 26 that is in agreement with the torque wheel results shown in figures 27-30.

The burnished lining tests of the FWD vehicle in the LLV condition are shown in figures 31-35. The single axle test in the LLV loading condition with burnished linings projects the FWD vehicle's brake balance to be more rear biased (fig 31) than any of the individual stops shown in figures 32-35. A similar finding is noted from the GVW tests of the FWD vehicle with burnished linings shown in figures 36-40. Here, the single axle projection of vehicle brake balance is shown in figure 36 and the individual ramp stops are shown in figures 37-40. In this case, the single axle method underestimates the degree of front axle adhesion utilization, and substantially overestimates that of the rear axle. This is in contrast to the earlier case with the RWD vehicle where the converse was true.

The GM tests of both front and rear wheel drive vehicles show the single axle test procedure has several shortcomings in determining the actual vehicle brake balance.

The first shortcoming identified is in the method of determining holdoff pressures for both the front and rear brakes. In FMVSS 135, the method called for is to elevate the vehicle on a hoist, and have a colleague slowly apply the brakes while one turns each of the wheels by hand, feeling for the first sign of brake drag. This is not an acceptable method of determining holdoff pressure which is the pressure to provide <u>full</u> engagement of the friction material and the braking surface. The manual method of determining holdoff pressure proposed for FMVSS 135 will generally underestimate the true holdoff pressure.

A second shortcoming is the determination of front vs rear line pressure relationships in FMVSS 135. In particular, using a static floor check of front vs rear line pressure is not a reliable method of establishing the dynamic properties of proportioning valves, particularly at higher apply rates.

A third difficulty is in determining vehicle deceleration by timing a velocity change. While this procedure is theoretically correct, an accurate determination is difficult since when the change in velocity is small enough to allow reasonable assurance of constant deceleration, the time interval is too short to be measured easily, and when the time interval is long enough to be measured conveniently, the velocity change is too large to assure a constant deceleration.

A fourth problem is in assuming that front and rear brake outputs at given values of line pressure are constant regardless of whether the other axle is doing any braking. For example, the single axle procedure calls for establishing a front line pressure value to achieve a given deceleration during the pre-snubs which seeks to determine the total brake force necessary to develop the target rate of deceleration. In later phases of this same test procedure, the line pressure established in the pre-snubs is applied to either the fronts alone or the rears alone, and a proportion of front to rear brake force is calculated. The principal technical problem with this technique is that friction materials are sensitive to their operating temperature, and when the axles are operated alone rather than as a system each must absorb the <u>total</u> vehicle energy. Thus, much higher temperatures will be generated in the active axle brake linings than when all brakes are functional.

The fact that these problems can be of a significant magnitude is evidenced by the adhesion utilization plots that have been reviewed above, in particular Figures 1, 21, and 31. In these figures, the front and rear adhesion utilization lines both lie on one side of the neutral balance line at the same deceleration. Since this is impossible behavior, it illustrates the errors which can occur when using this balance determination technique.

Note also that the single axle projection of the FWD vehicle in the unladen condition with burnished linings (figure 31) shows a rear axle limited brake balance even though all the ramp stops gathered in this same test condition show front axle limited brake balance at most decelerations. Judging from the predicted results of the single axle procedure, this vehicle could be declared out of compliance with FMVSS 135, even though 3 of the 4 ramp stops show the vehicle to be acceptable. The unreliability of this test procedure, as revealed in this comparison, makes it unacceptable for use in FMVSS 135.

The RTP test results for both front and rear wheel drive vehicles are shown in figures 41-48. These may be compared to the equivalent vehicle loading, lining burnish, and drive configuration results described earlier. While the results obtained with the RTP generally agree with those obtained with torque wheels or the single axle method, the match is not perfect in all cases. The RTP measures true road force and includes such effects as tires and drive train retarding forces. These effects are treated indirectly by the single axle procedure.

While torque wheels and digital data acquisition equipment remain the method of choice for vehicle brake system development testing, the RTP offers many advantages for a vehicle test in the regulatory environment. The RTP measures true road forces, requires minimum vehicle modification, and allows a short test procedure easily conducted in a brief period of time. No inventory of torque wheels, or vehicle instrumentation is required. Other than the initial capital expenditure to equip the test facility, test costs are kept to a reasonable minimum.

During the GRRF visit to the GM Proving Ground on October 2, 1985, a particular vehicle was run over the RTP four times in succession to demonstrate the technique to the various groups. Some of the delegates apparently left the test facility with the impression that the test to test variability observed in these particular vehicle evaluations (figures 49-52) was due to instrumentation error rather than vehicle variation. Having conducted hundreds of RTP tests over the past several years, GM is confident of both the reliability and validity of the RTP technique. We believe the differences between these four test results actually reflect the stop to stop variation resulting from differing lining temperatures and other vehicle factors.

The delegates to the GRRF discussed the Swedish test procedure which uses a simple "skid check". This procedure calls for identifying first axle lock sequence on one test surface, and will tell very little about a vehicle's overall brake balance. For an accurate assessment of a vehicle's brake balance it is necessary to obtain measurements over a broad range of decelerations. The Swedish procedure, and the single axle procedure proposed in FMVSS 135 both fail to provide this capability.

Before any particular test technique for adhesion utilization is considered for adoption in a harmonized brake standard, considerable testing and validation of the procedure should be conducted to assure that the procedure presents a fair assessment of the condition to be regulated. Such a test program should include representatives of automobile manufacturers and regulatory groups.

The problems associated with developing a test procedure and instrumentation that would be acceptable to all parties are avoided by adopting the current adhesion utilization certification procedure used in ECE R13. While the ECE R13 approach to vehicle brake balance certification allows some freedom for the manufacturer to select the values of foundation brake output, it does constrain the manufacturer to be able to defend the nominal values selected to develop the adhesion utilization curves prescribed by Annex 10. The European delegates to the GRRF have related no problems with the procedure of ECE R13, Annex 10, and in general, they do not perceive a need for any physical test for adhesion utilization.

Adopting the ECE R13 approach to adhesion utilization certification offers several advantages over a vehicle test requirement. Among these are the freedom provided the manufacturer to balance the nominal vehicle very close to ideal brake balance in the lightly loaded vehicle condition, and thereby reduce the stopping distance penalty incurred by emphasizing front axle limited brake balance for the extreme of variability distribution. As discussed in Appendix 4, Brake Balance Influence on Stopping Distance, forcing brake balance in all loading conditions to one side or the other of the ideal inevitably increases stopping distance. By adopting the ECE R13 approach to adhesion utilization requirements, the extent to which stopping distances are increased would be minimized.

The second major advantage to certification of brake balance by nominal design calculation is the avoidance of an extensive research program focused upon identifying a reasonable range of tolerances or limits that are consistent with the behavior of real brake systems. As mentioned earlier, the influence of variations in brake output upon vehicle brake balance and stopping distance is very complex and dependent not only upon the nominal brake balance of the vehicle, but also upon the specific test procedure employed and the degree of brake burnish that exists at the time of test. More precisely, if the adhesion utilization test of a specific vehicle is to be combined with the relatively short burnish procedures called for in FMVSS 135 and draft proposal R.88, then considerable additional testing is necessary to determine the magnitude of burnish effects upon balance tests in the almost green condition that would exist at the time of those tests.

With all these problems facing the use of a physical test for adhesion utilization, the probability of gaining world wide acceptance for a brake standard that requires a vehicle test is substantially reduced. Regulators should carefully consider the issue of inherent variability in vehicle adhesion utilization before adopting such a requirement. Based on our extensive collection of data related to the issue of variability in vehicle brake balance, GM believes that the addition of a test for adhesion utilization or brake balance to an international brake standard presents many problems; that much additional study and testing need to be completed before a totally acceptable test could be developed; and that any such test would require large tolerances on the requirements. With the world population of vehicles including many different types of vehicle configurations and brake designs, the total range of vehicle brake balance variability is impracticable to determine at this time.

Having reviewed all the information related to brake balance variability, it seems clear that the inclusion of a specific vehicle test for adhesion utilization in an international braking standard is more difficult than would be justified. The extended satisfactory experience of the European community with the ECE R13 approach would indicate that the inclusion of such a test in FMVSS 135 should not be necessary. Likewise, the stopping distance penalty associated with the use of such a test would be a disservice to the motoring public, in GM's view. Finally, the costs of implementation for any technically acceptable test hardware would likely preclude this provision from being adopted in type approval countries.

FIG. 1

135 EVALUATION, SINGLE AXLE METHOD

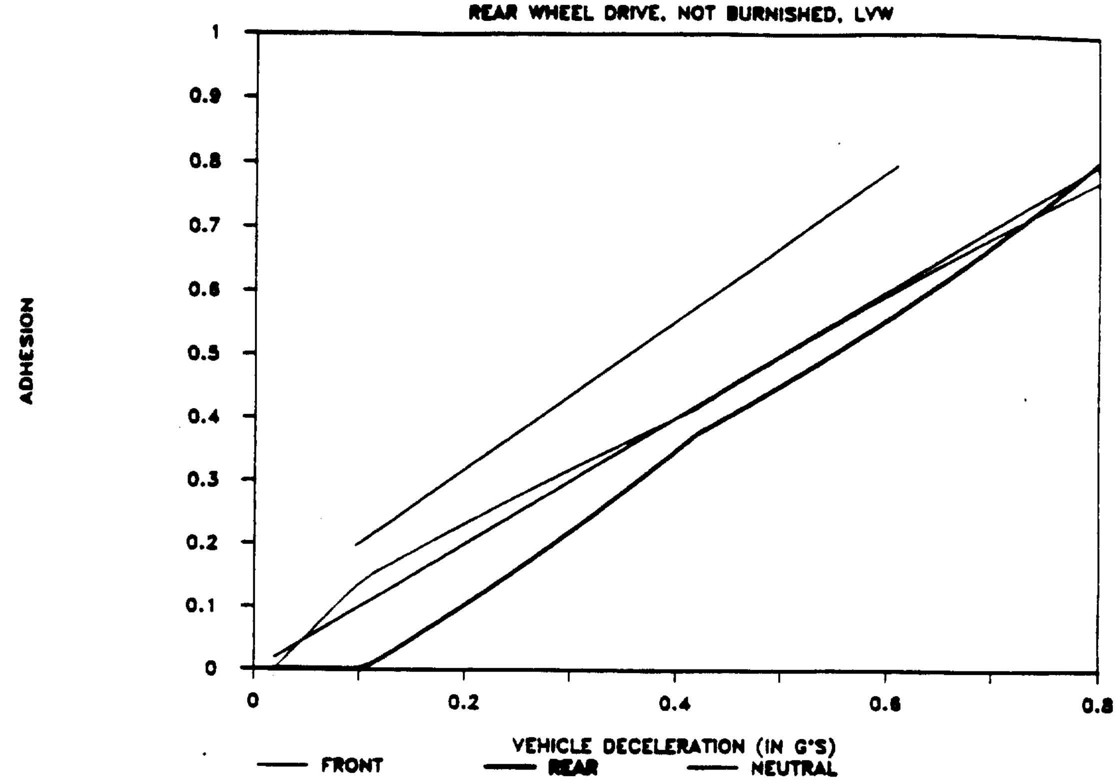


FIG. 2

135 EVALUATION, SNUBS W/ TORQUE WHEELS

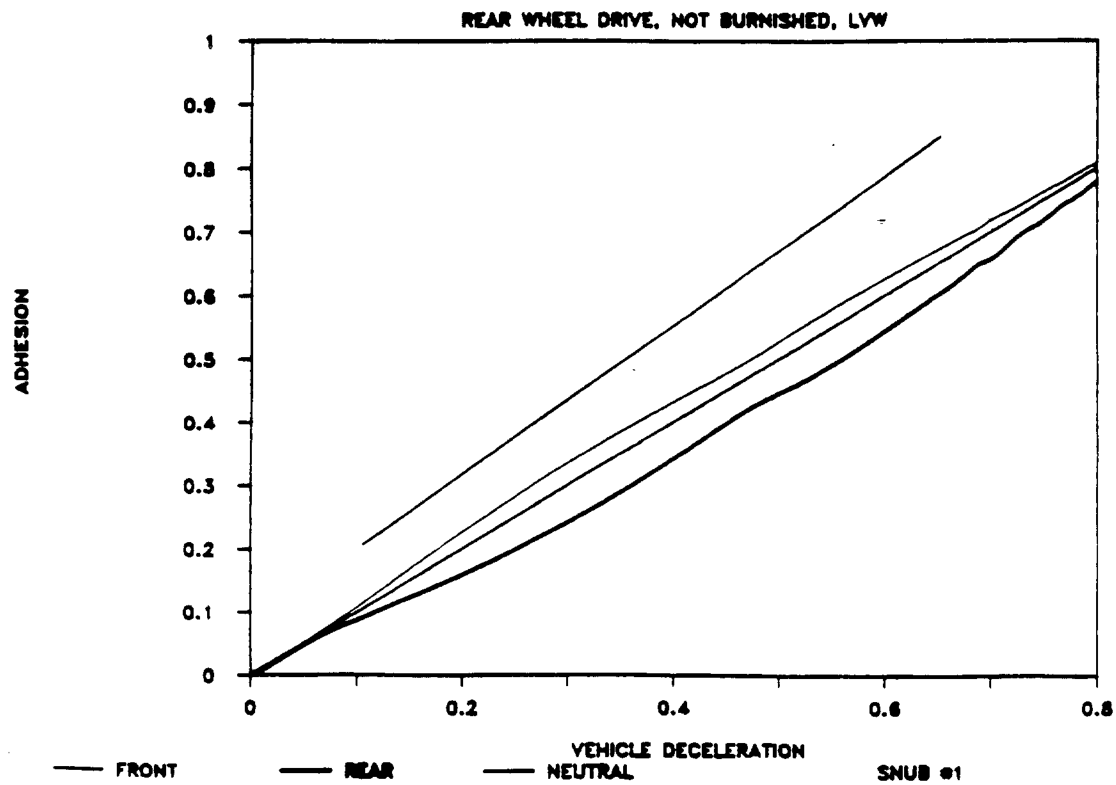


FIG. 3

135 EVALUATION, SNUBS W/ TORQUE WHEELS

REAR WHEEL DRIVE, NOT BURNISHED, LVW

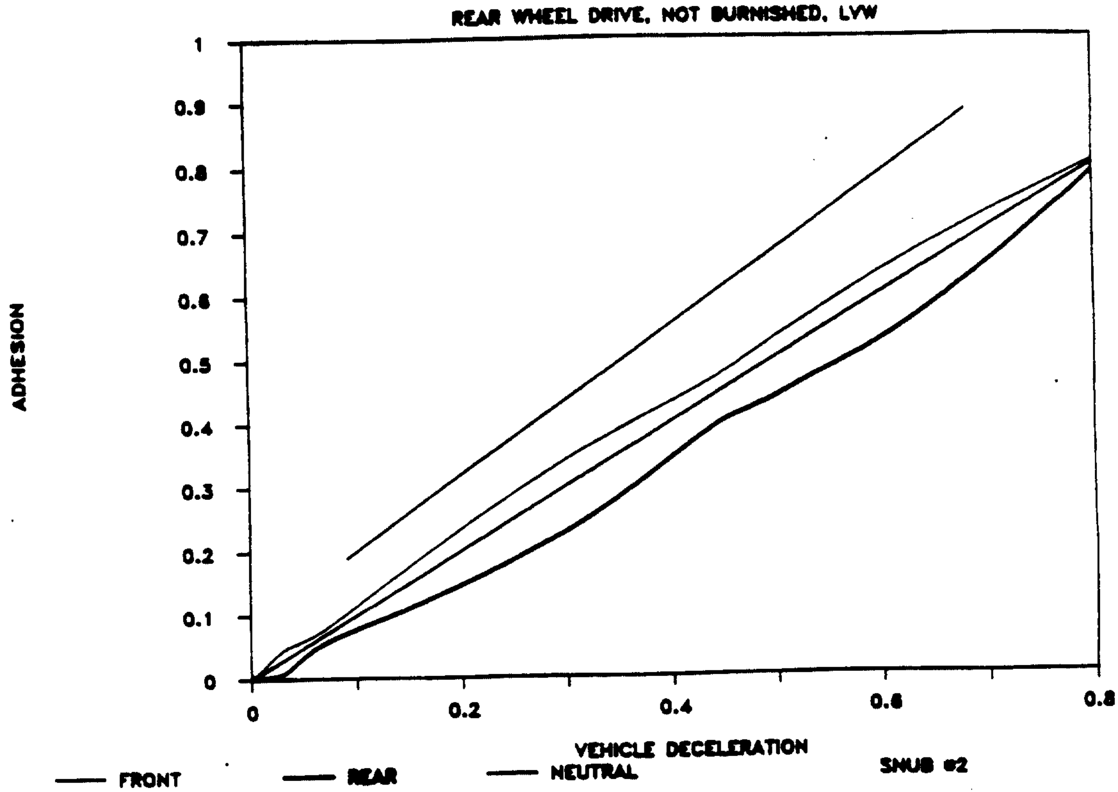


FIG. 4

135 EVALUATION, SNUBS W/ TORQUE WHEELS

REAR WHEEL DRIVE, NOT BURNISHED, LVW

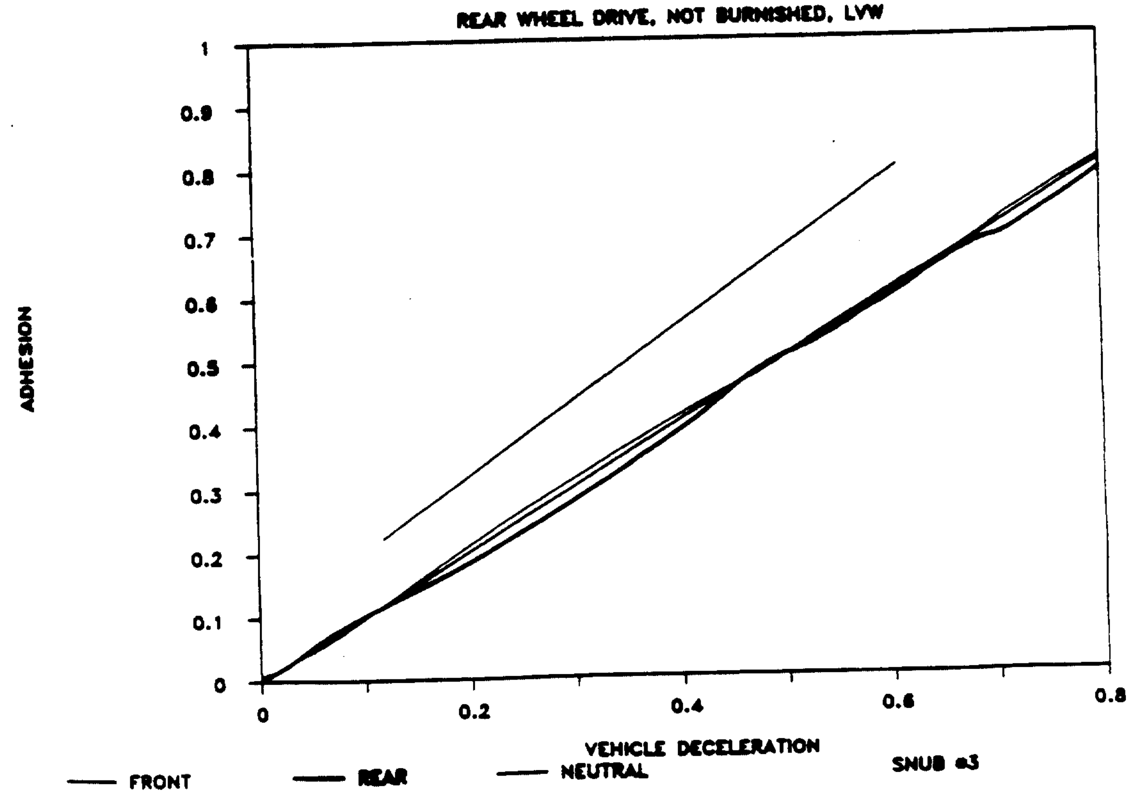


FIG. 5

135 EVALUATION, SNUBS W/ TORQUE WHEELS

REAR WHEEL DRIVE, NOT BURNISHED, LVW

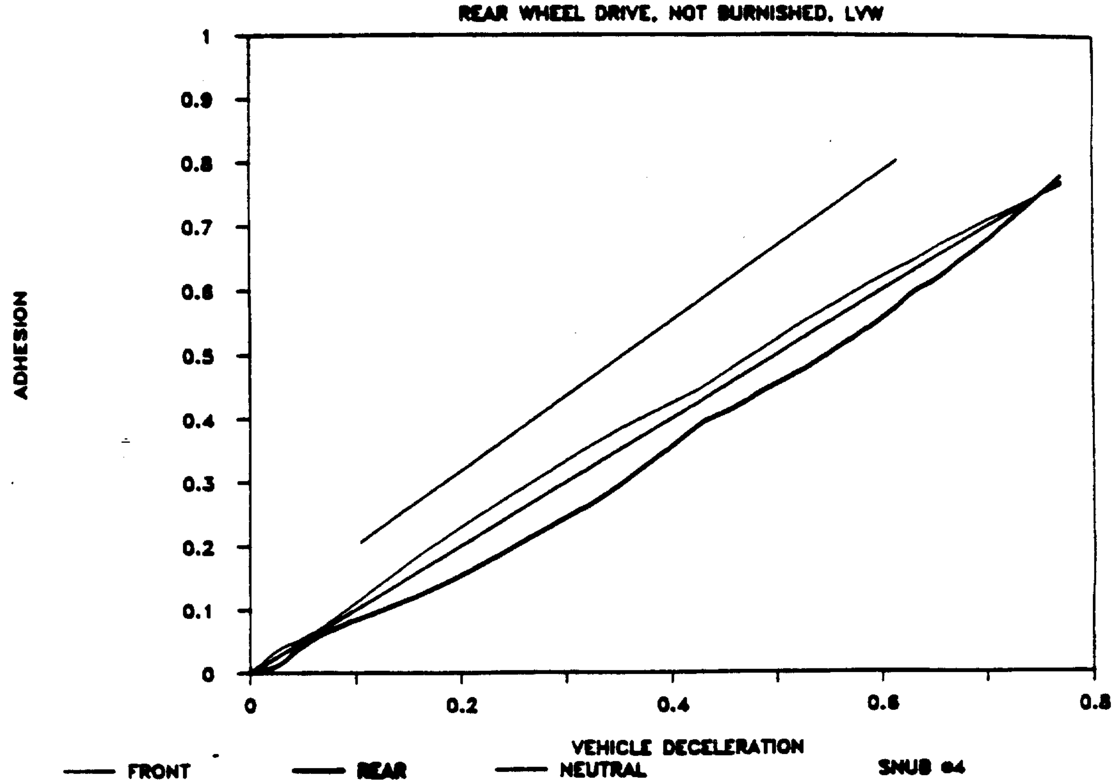


FIG. 6

135 EVALUATION, SINGLE AXLE METHOD

REAR WHEEL DRIVE, NOT BURNISHED, GVW

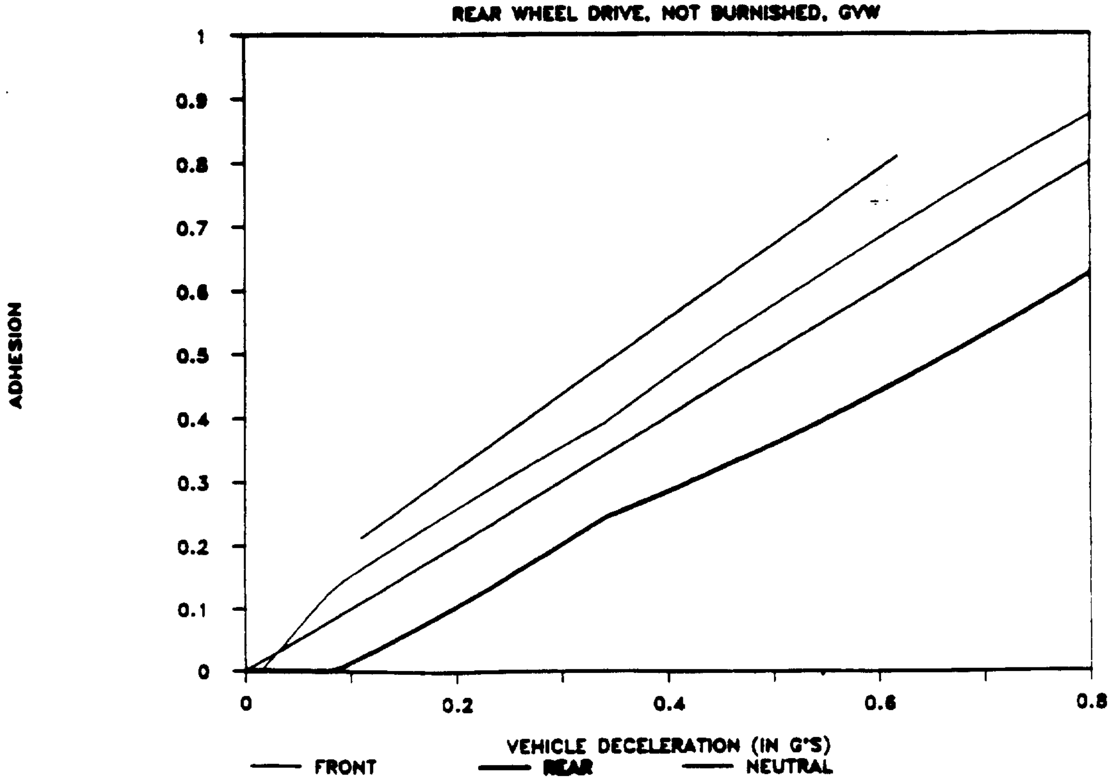


FIG. 7

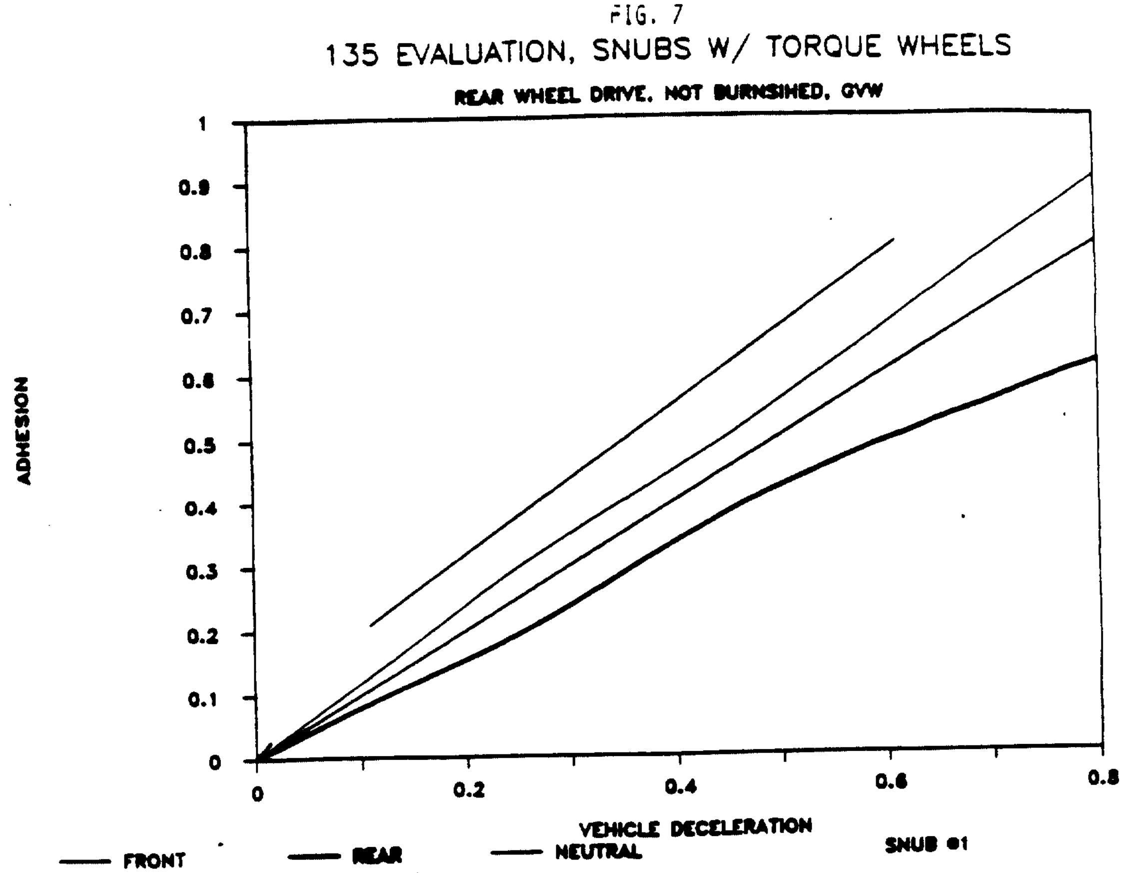

135 EVALUATION, SNUBS W/ TORQUE WHEELS
REAR WHEEL DRIVE, NOT BURNISHED, GVW
ADHESION
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
VEHICLE DECELERATION
FRONT
REAR
NEUTRAL
SNUB #1

FIG. 8

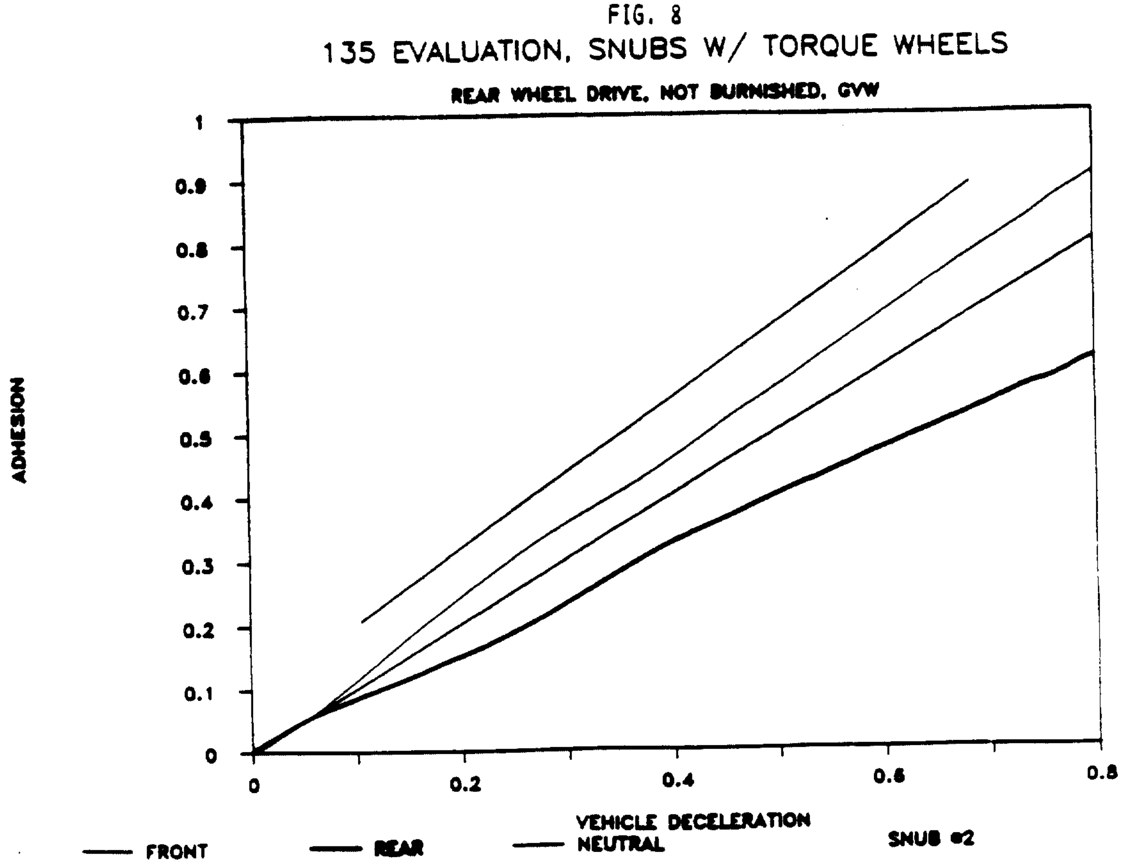

135 EVALUATION, SNUBS W/ TORQUE WHEELS
REAR WHEEL DRIVE, NOT BURNISHED, GVW
ADHESION
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
VEHICLE DECELERATION
FRONT
REAR
NEUTRAL
SNUB #2

FIG. 9

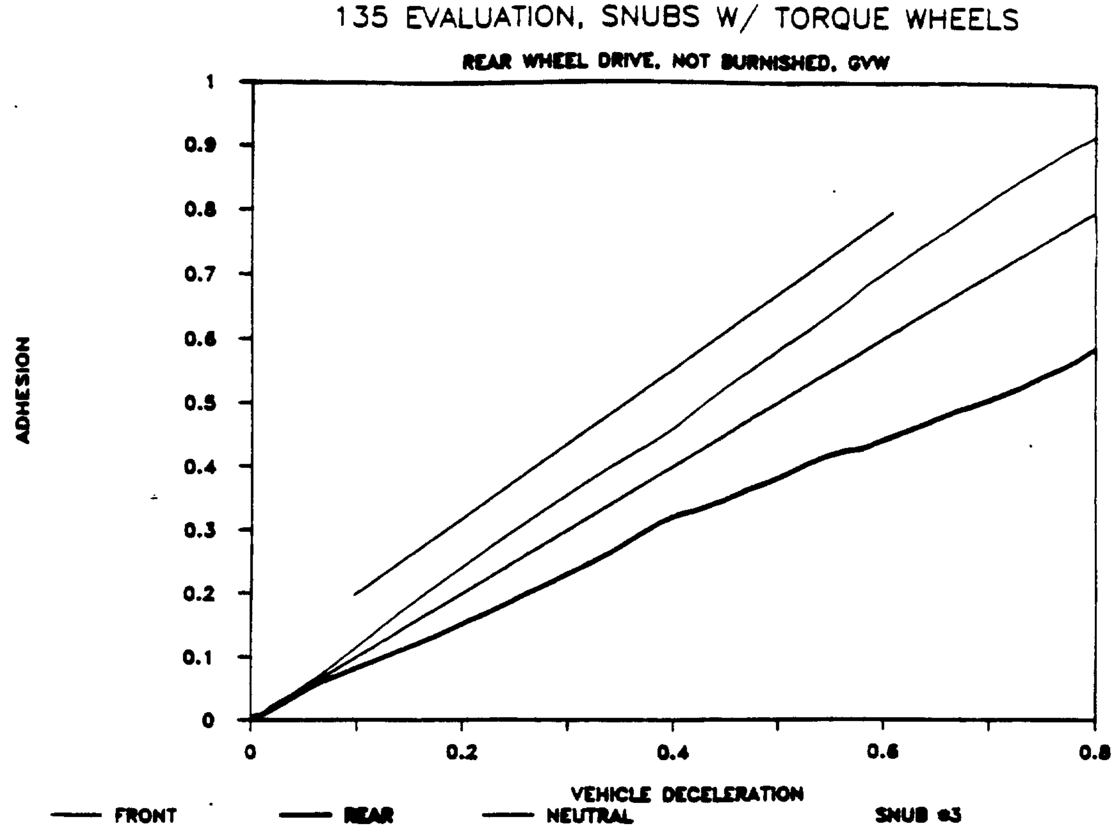

135 EVALUATION, SNUBS W/ TORQUE WHEELS
REAR WHEEL DRIVE, NOT BURNISHED, GVW
ADHESION
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
VEHICLE DECELERATION
FRONT
REAR
NEUTRAL
SNUB #3

FIG. 10

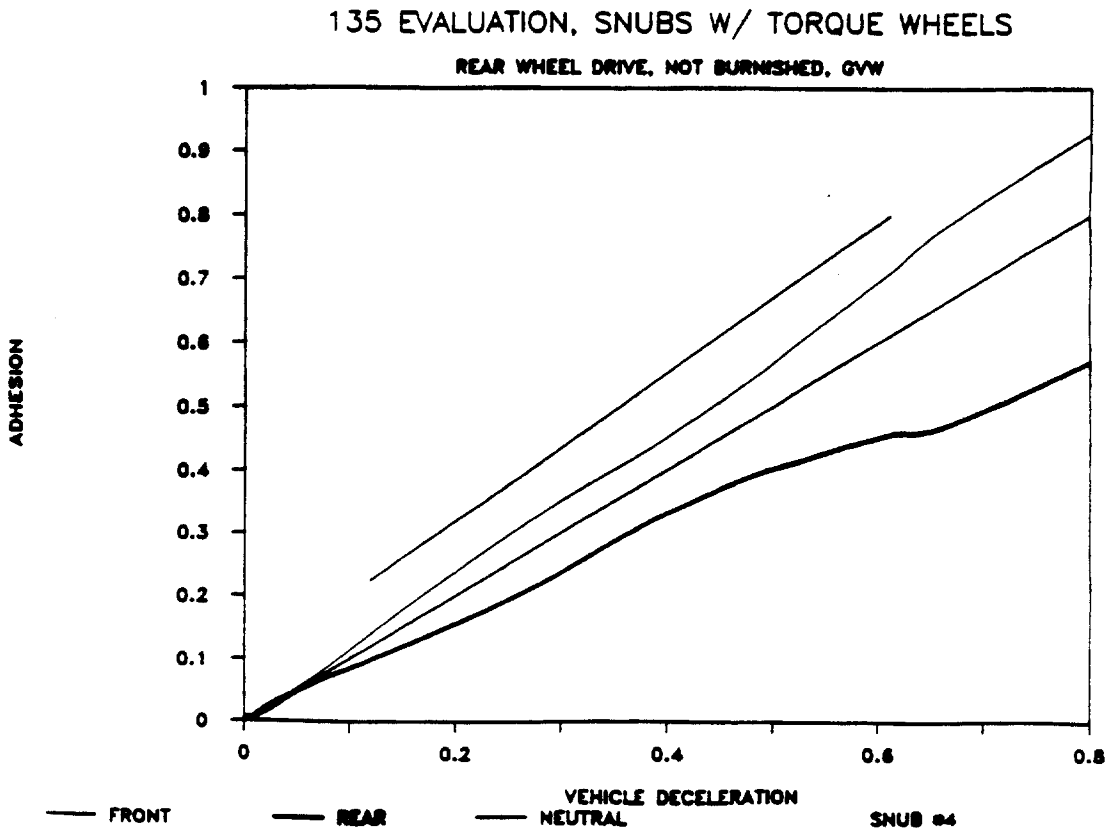

135 EVALUATION, SNUBS W/ TORQUE WHEELS
REAR WHEEL DRIVE, NOT BURNISHED, GVW
ADHESION
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
VEHICLE DECELERATION
FRONT
REAR
NEUTRAL
SNUB #4

FIG. 11

135 EVALUATION, SINGLE AXLE METHOD

REAR WHEEL DRIVE, BURNISHED, LVW

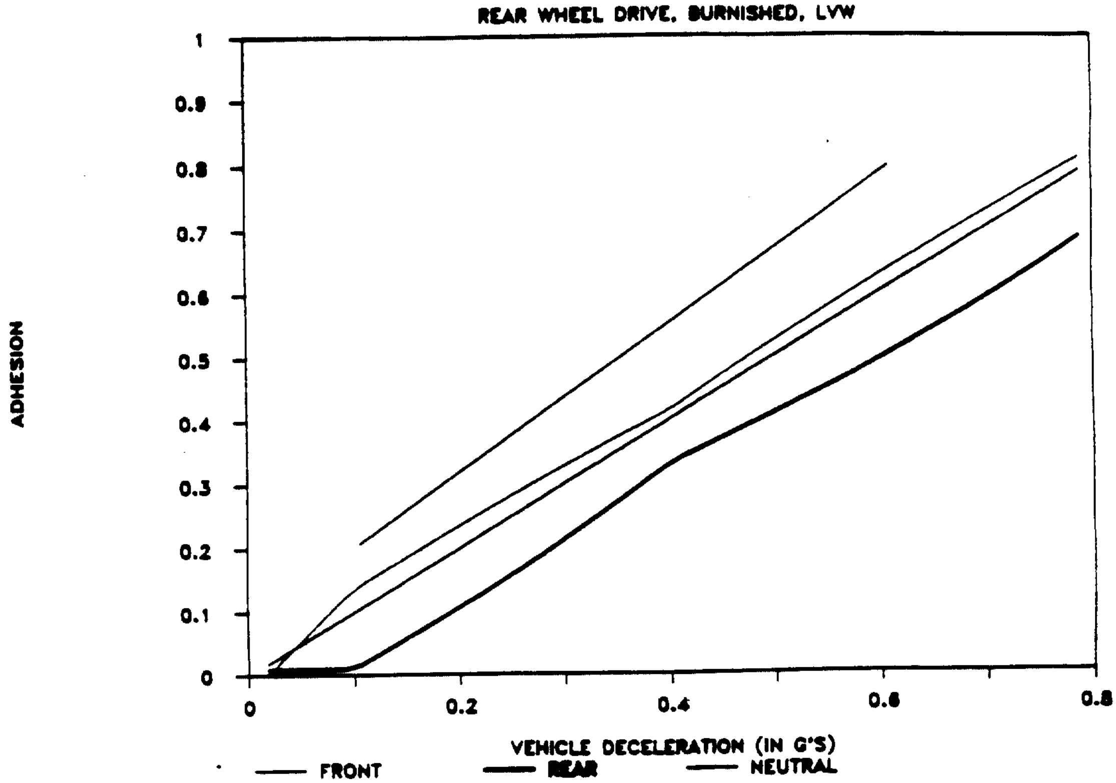


FIG. 12

135 EVALUATION, SNUBS W/ TORQUE WHEELS

REAR WHEEL DRIVE, BURNISHED, LVW

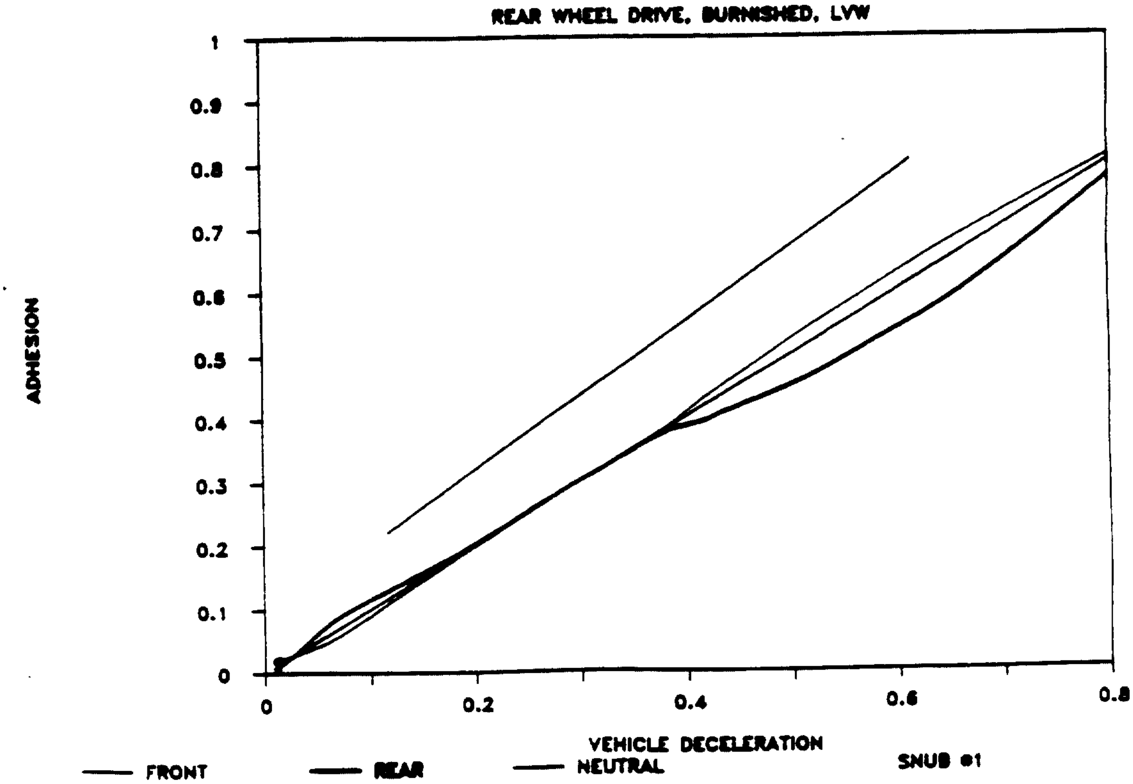


FIG. 13

135 EVALUATION, SNUBS W/ TORQUE WHEELS

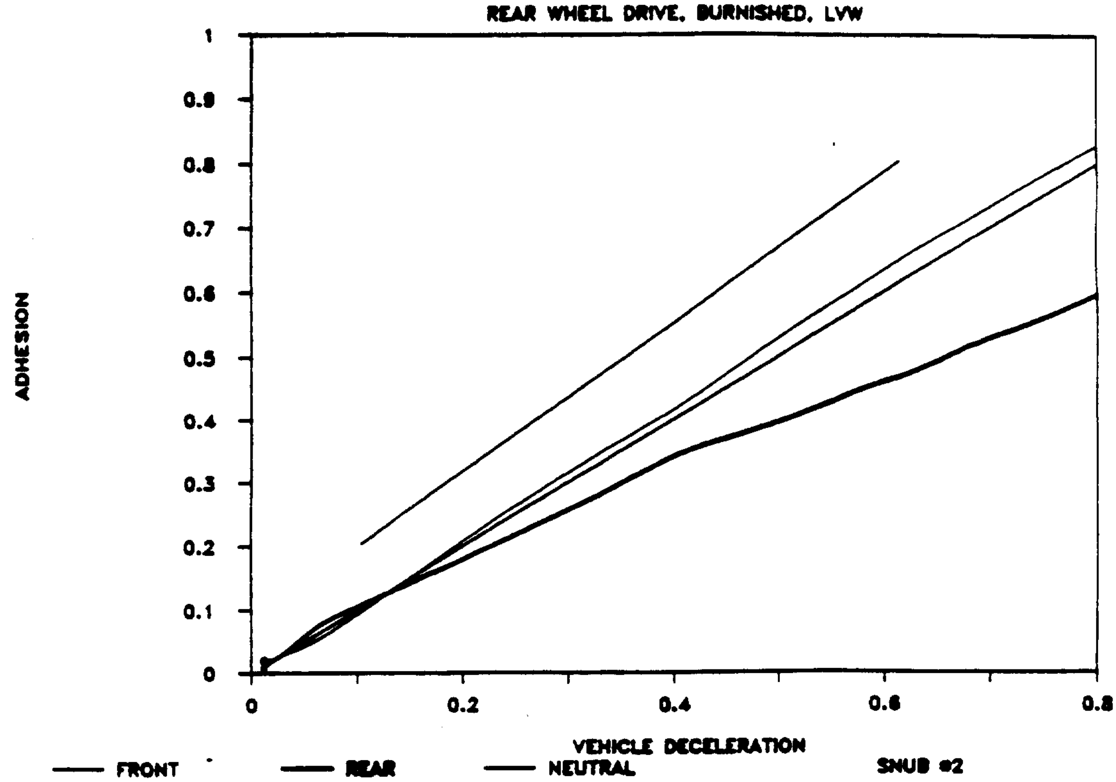


FIG. 14

135 EVALUATION, SNUBS W/ TORQUE WHEELS

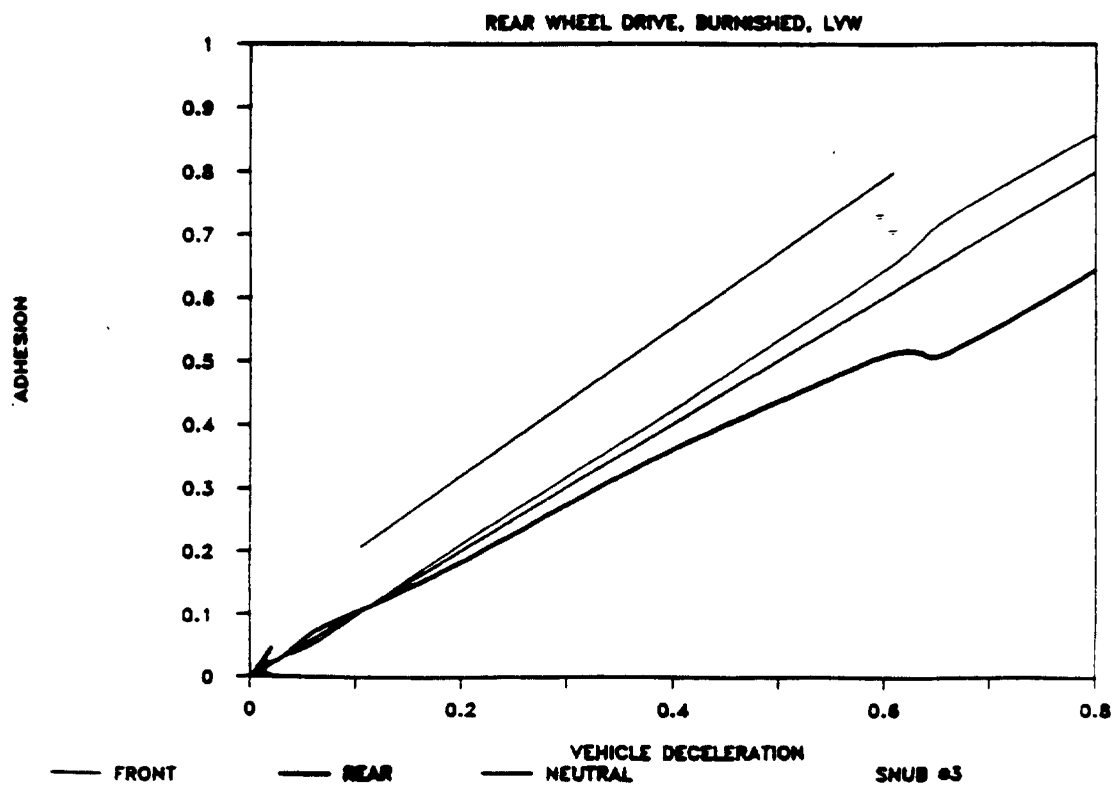


FIG. 15

135 EVALUATION, SNUBS W/ TORQUE WHEELS

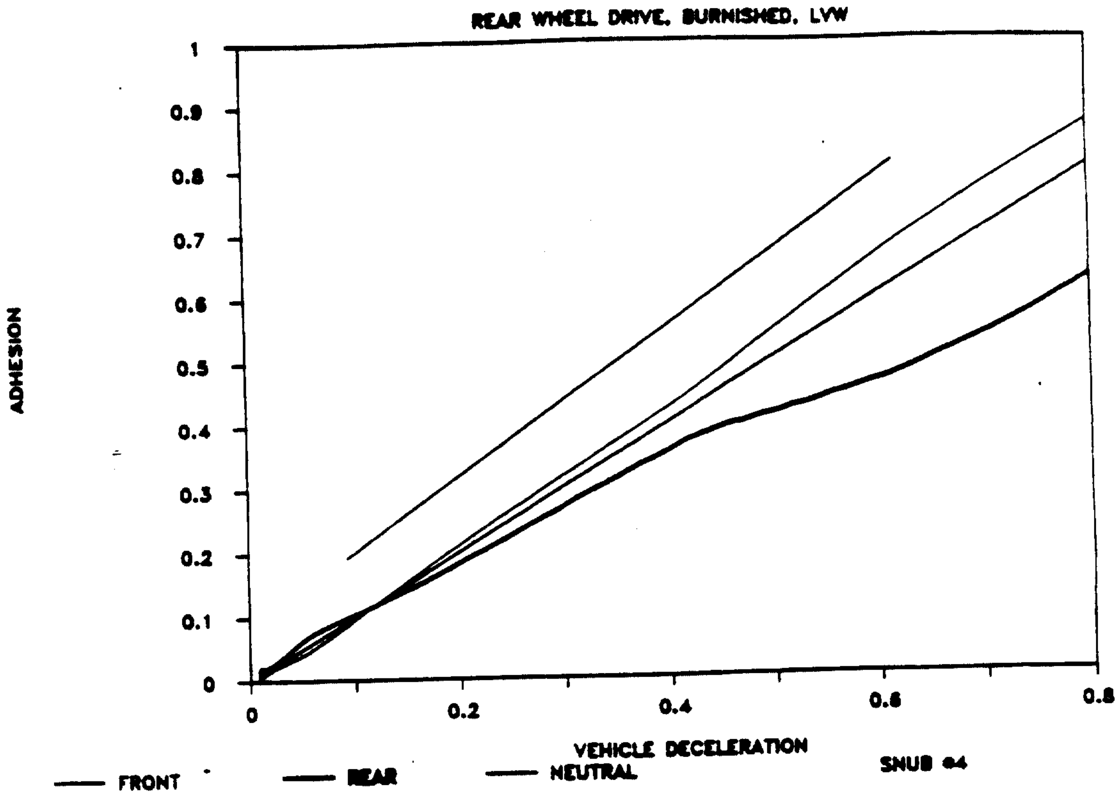


FIG. 16

135 EVALUATION, SINGLE AXLE METHOD

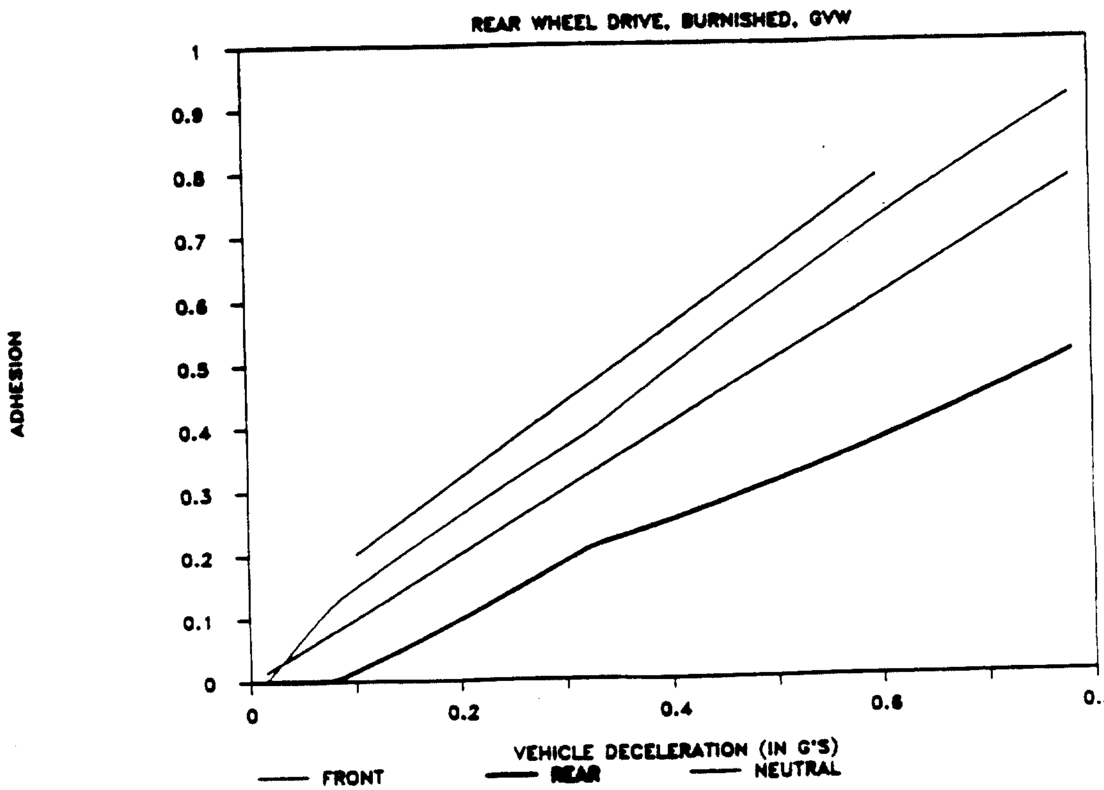


FIG. 17

135 EVALUATION, SNUBS W/ TORQUE WHEELS

REAR WHEEL DRIVE, BURNISHED, GVW

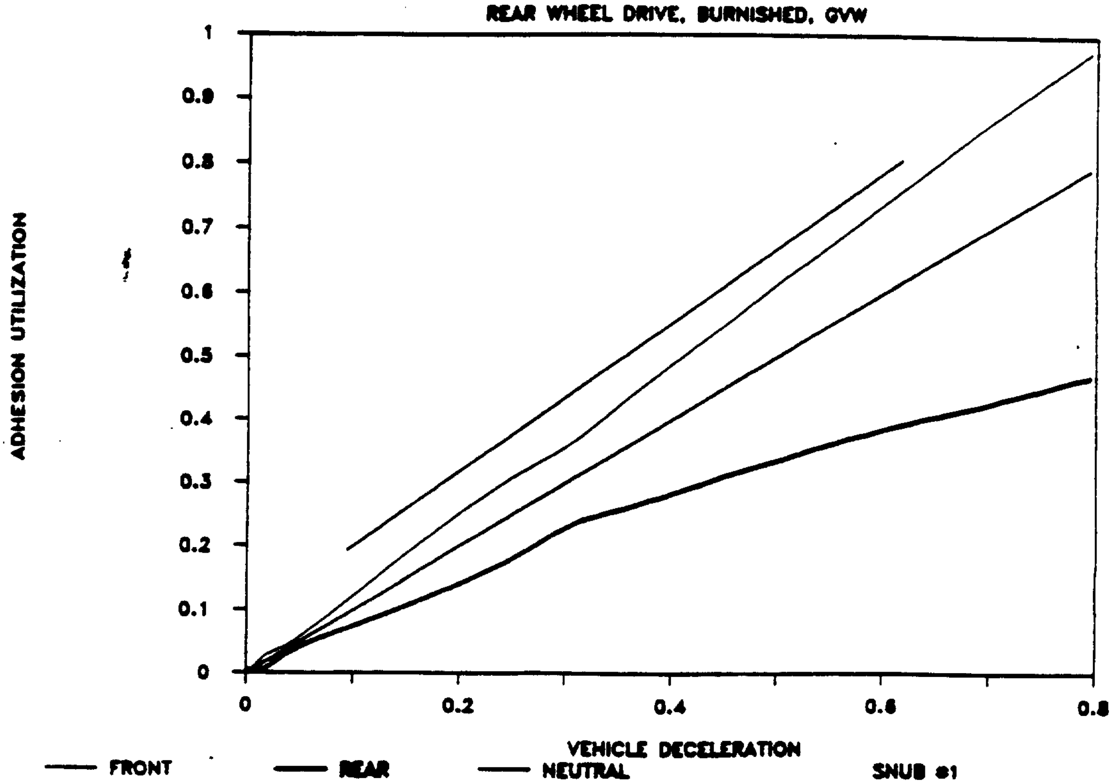


FIG. 18

135 EVALUATION, SNUBS W/ TORQUE WHEELS

REAR WHEEL DRIVE, BURNISHED, GVW

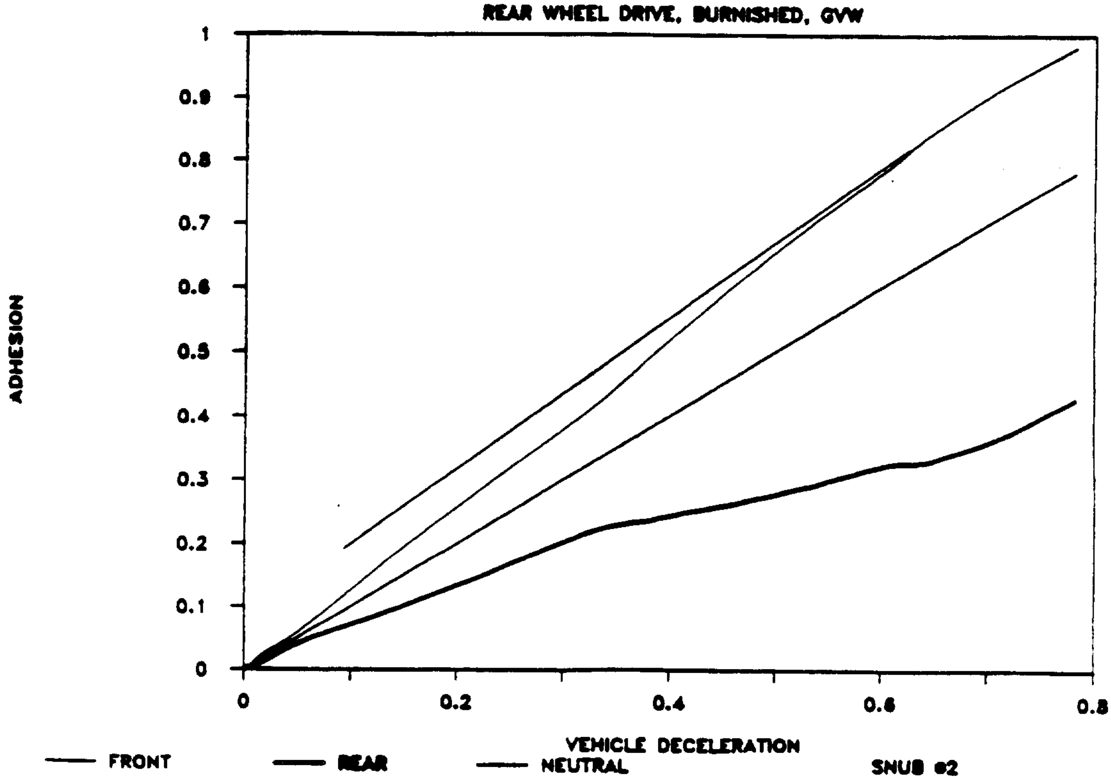


FIG. 19

135 EVALUATION, SNUBS W/ TORQUE WHEELS

REAR WHEEL DRIVE, BURNISHED, GVW

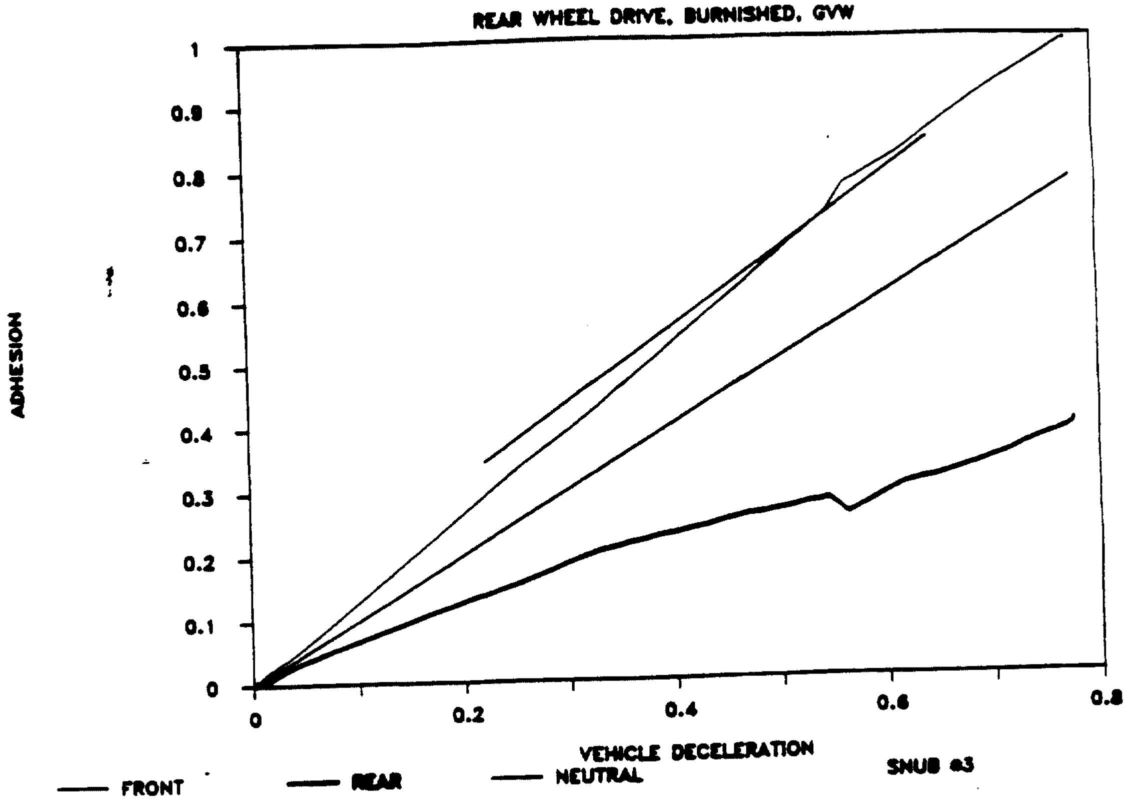


FIG. 20

135 EVALUATION, SNUBS W/ TORQUE WHEELS

REAR WHEEL DRIVE, BURNISHED, GVW

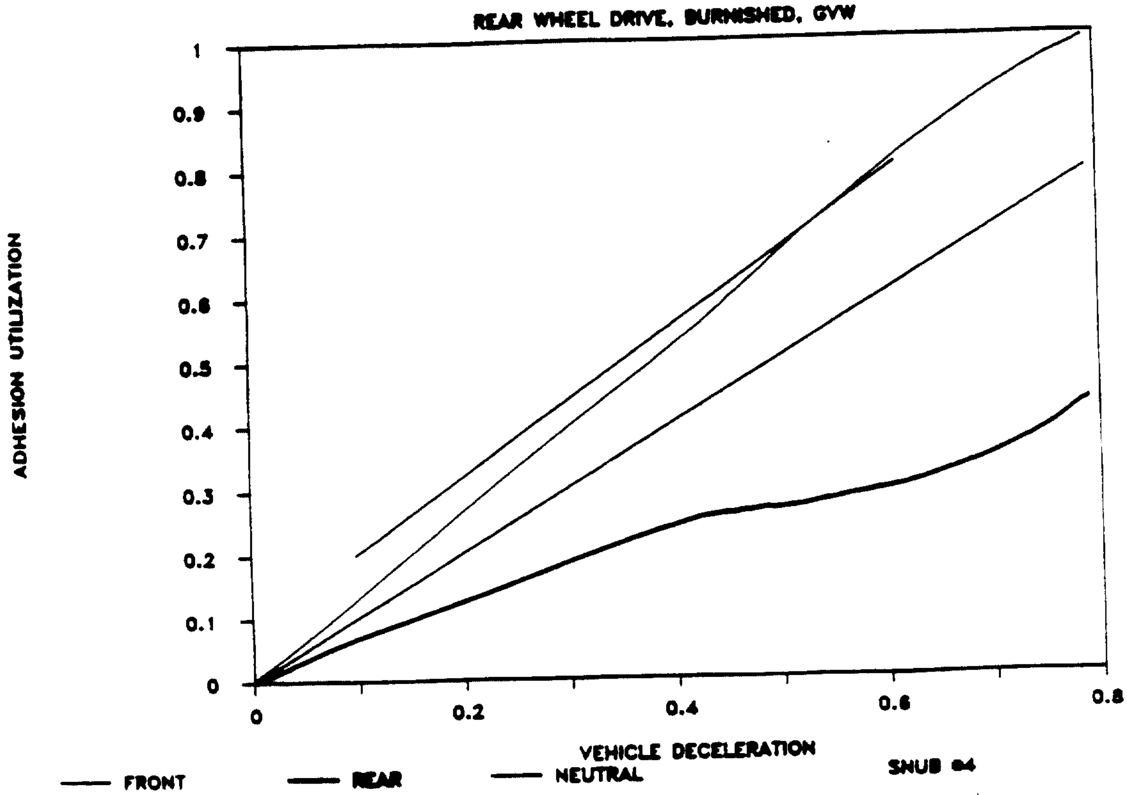


FIG. 21

135 EVALUATION, SINGLE AXLE METHOD

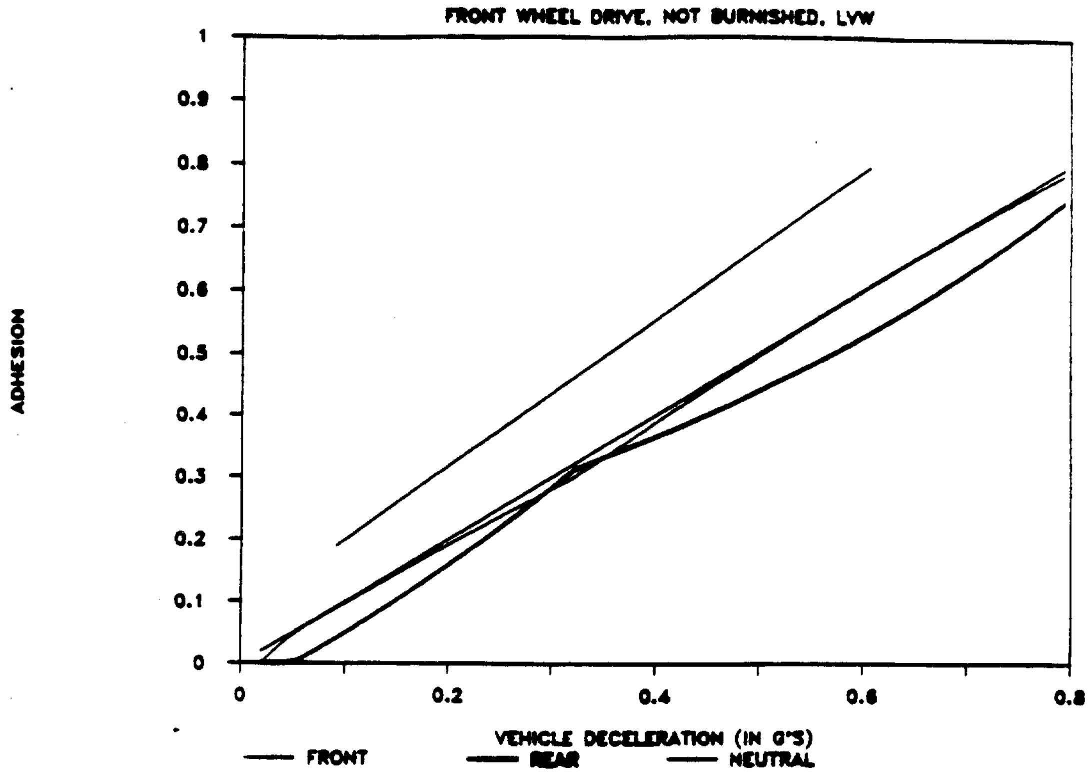


FIG. 22

135 EVALUATION, SNUBS W/ TORQUE WHEELS

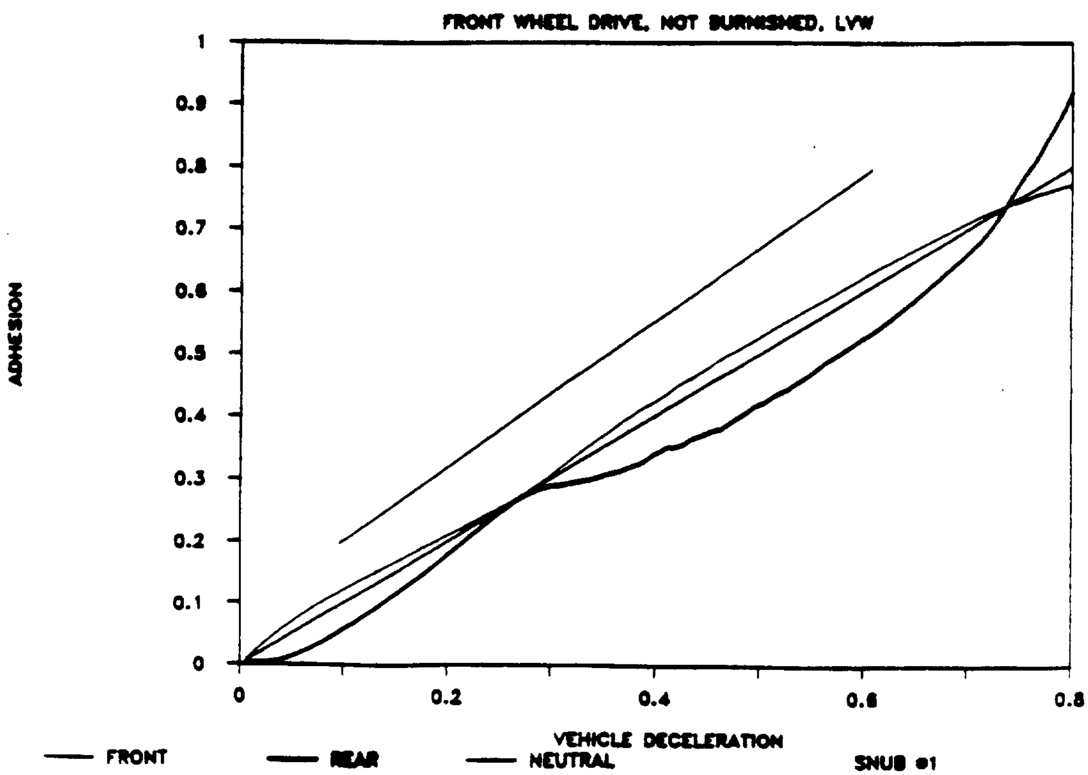


FIG. 23

135 EVALUATION, SNUBS W/ TORQUE WHEELS

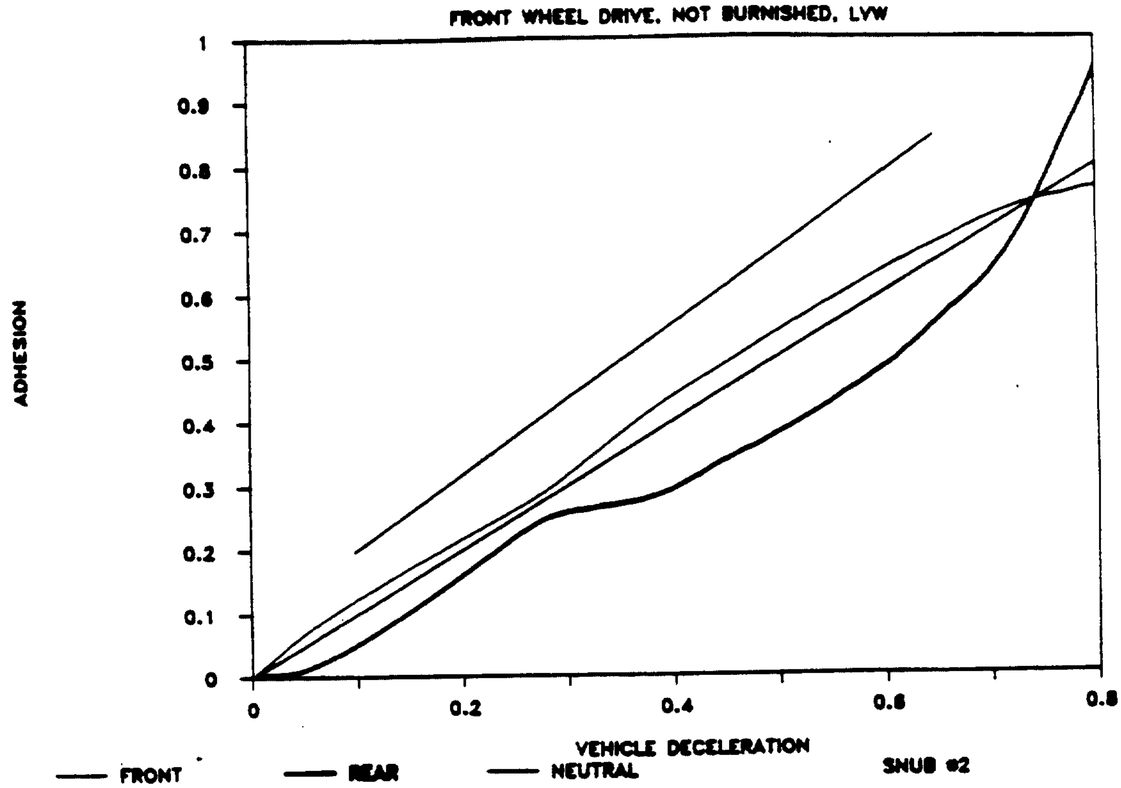


FIG. 24

135 EVALUATION, SNUBS W/ TORQUE WHEELS

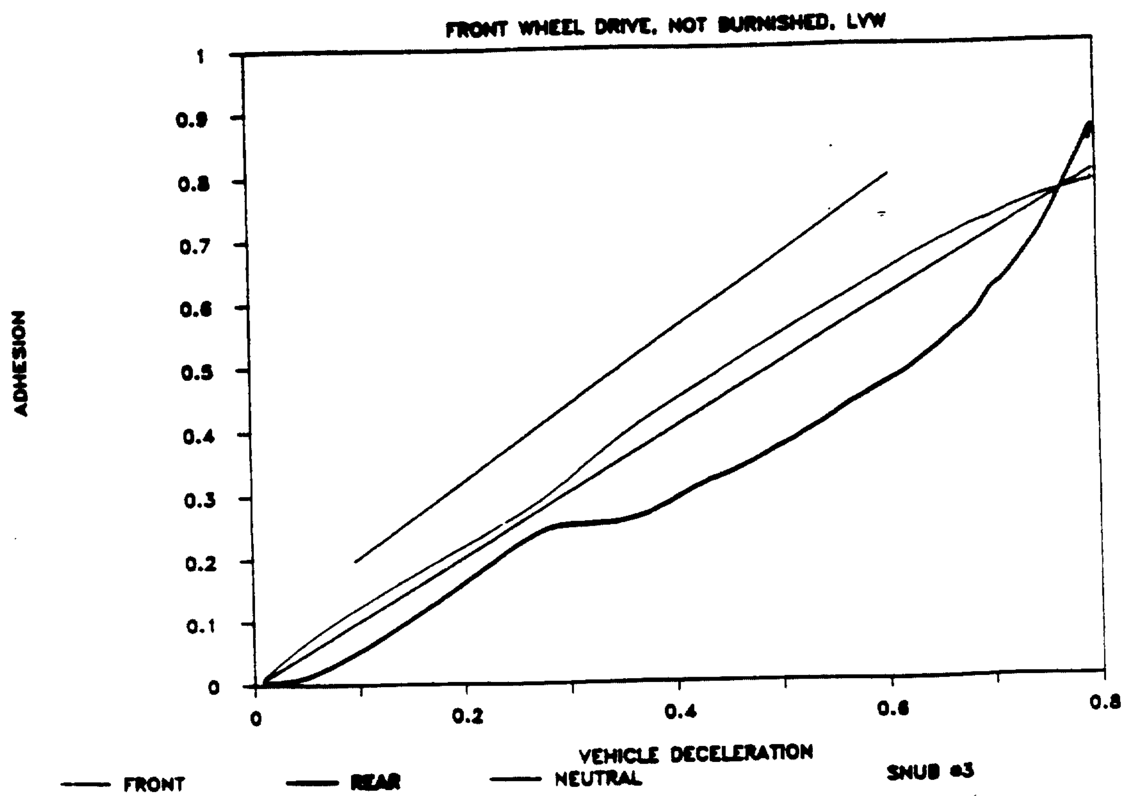


FIG. 25

135 EVALUATION, SNUBS W/ TORQUE WHEELS

FRONT WHEEL DRIVE, NOT BURNISHED, LVW

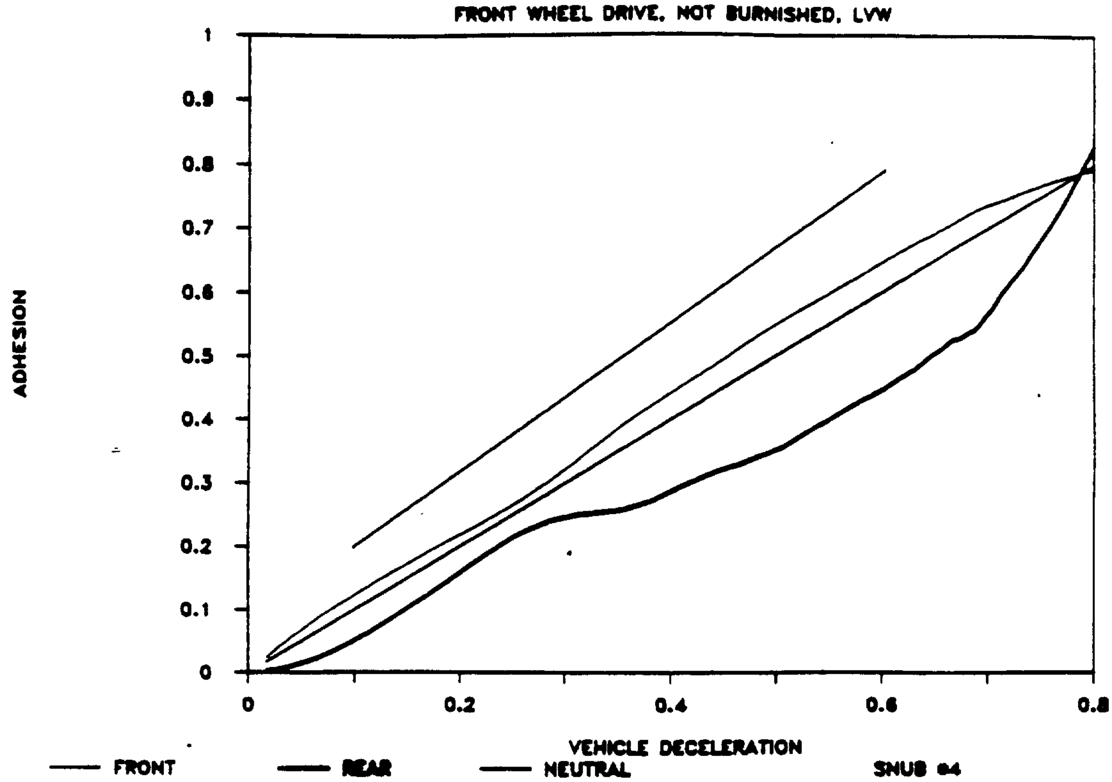


FIG. 26

135 EVALUATION, SINGLE AXLE METHOD

FRONT WHEEL DRIVE, NOT BURNISHED, GVW

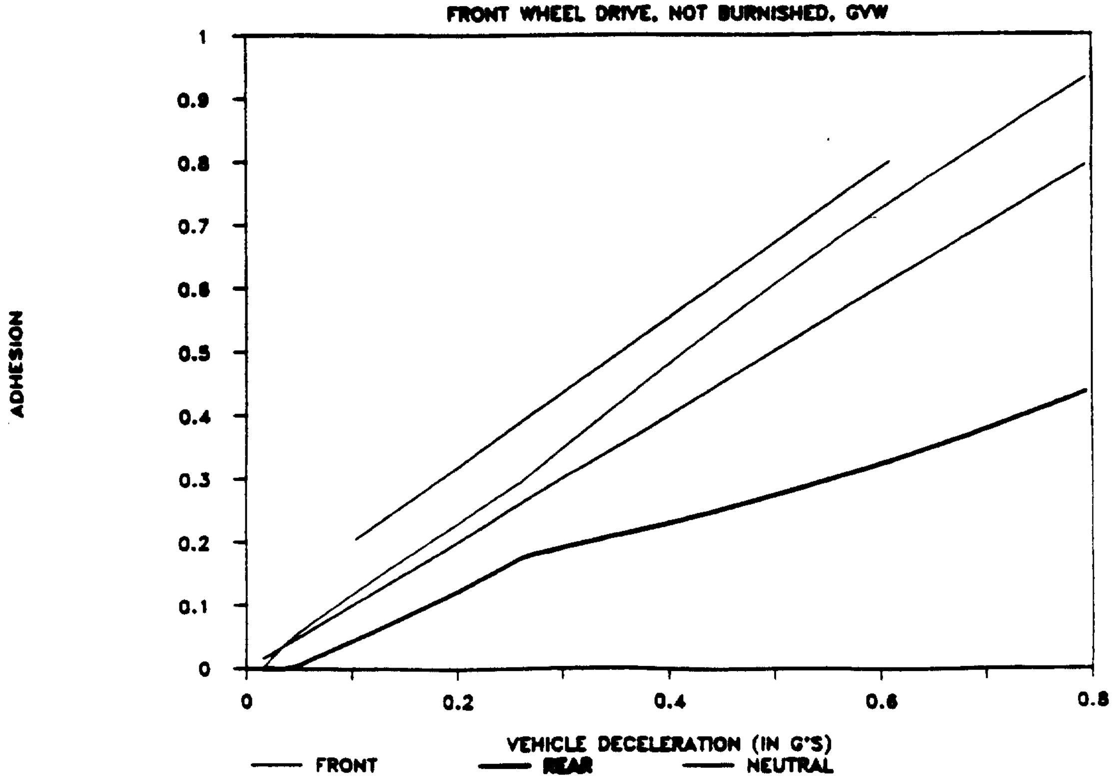


FIG. 27

135 EVALUATION, SNUBS W/ TORQUE WHEELS

FRONT WHEEL DRIVE, NOT BURNISHED, GVW

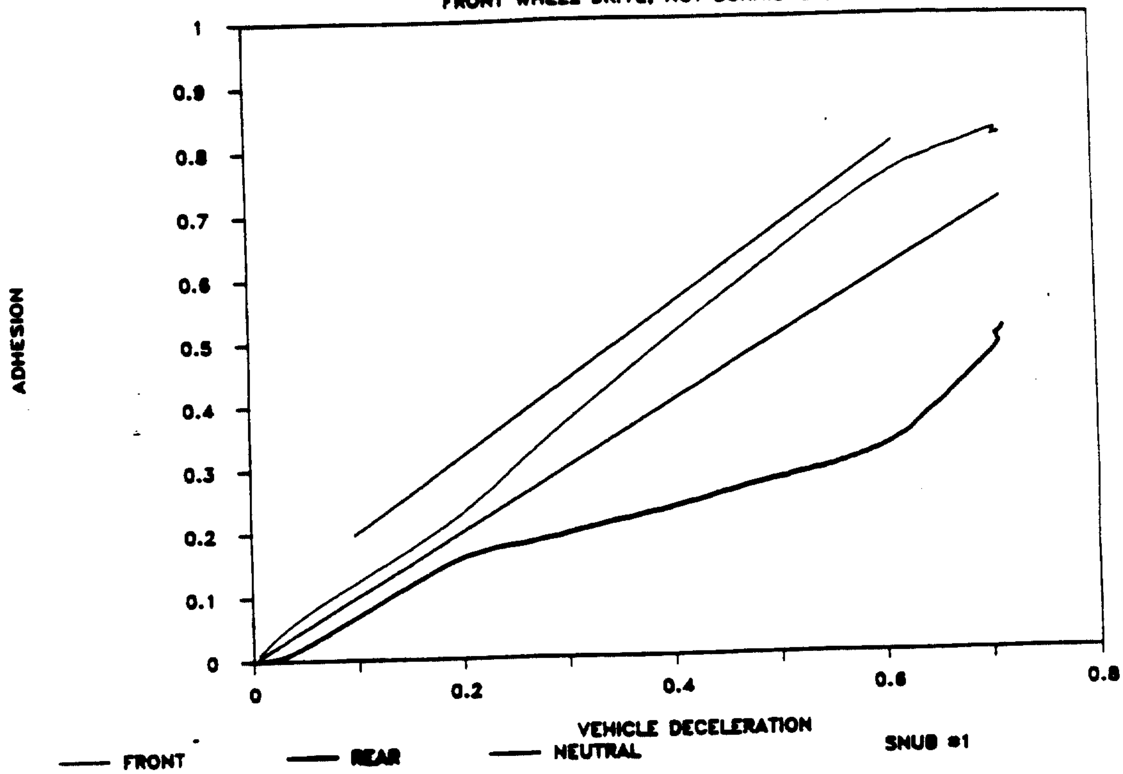


FIG. 28

135 EVALUATION, SNUBS W/ TORQUE WHEELS

FRONT WHEEL DRIVE, NOT BURNISHED, GVW

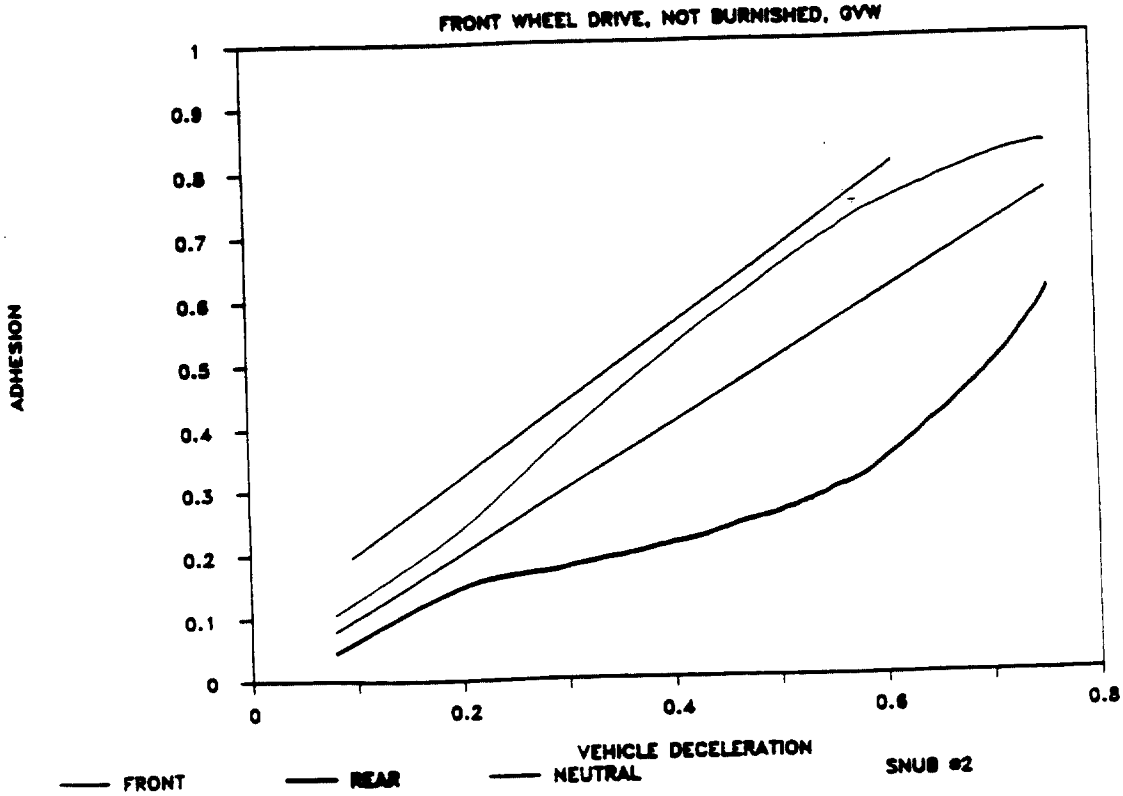


FIG. 29

135 EVALUATION, SNUBS W/ TORQUE WHEELS

FRONT WHEEL DRIVE, NOT BURNISHED, GVW

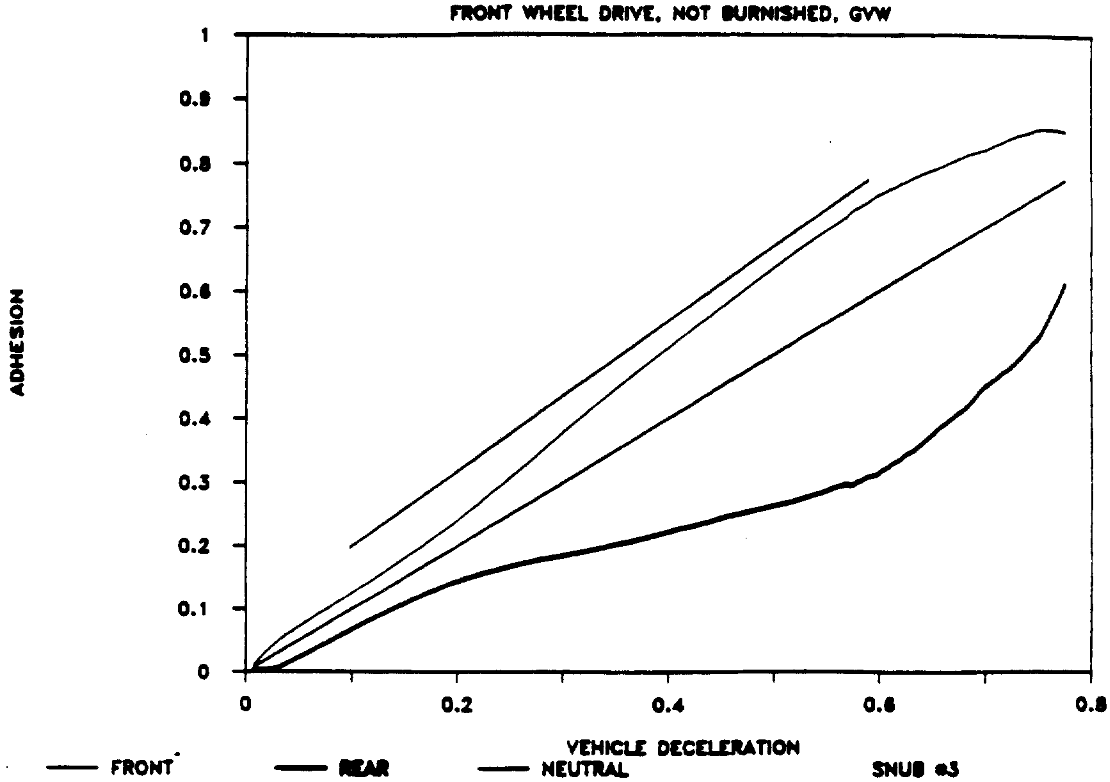


FIG. 30

135 EVALUATION, SNUBS W/ TORQUE WHEELS

FRONT WHEEL DRIVE, NOT BURNISHED, GVW

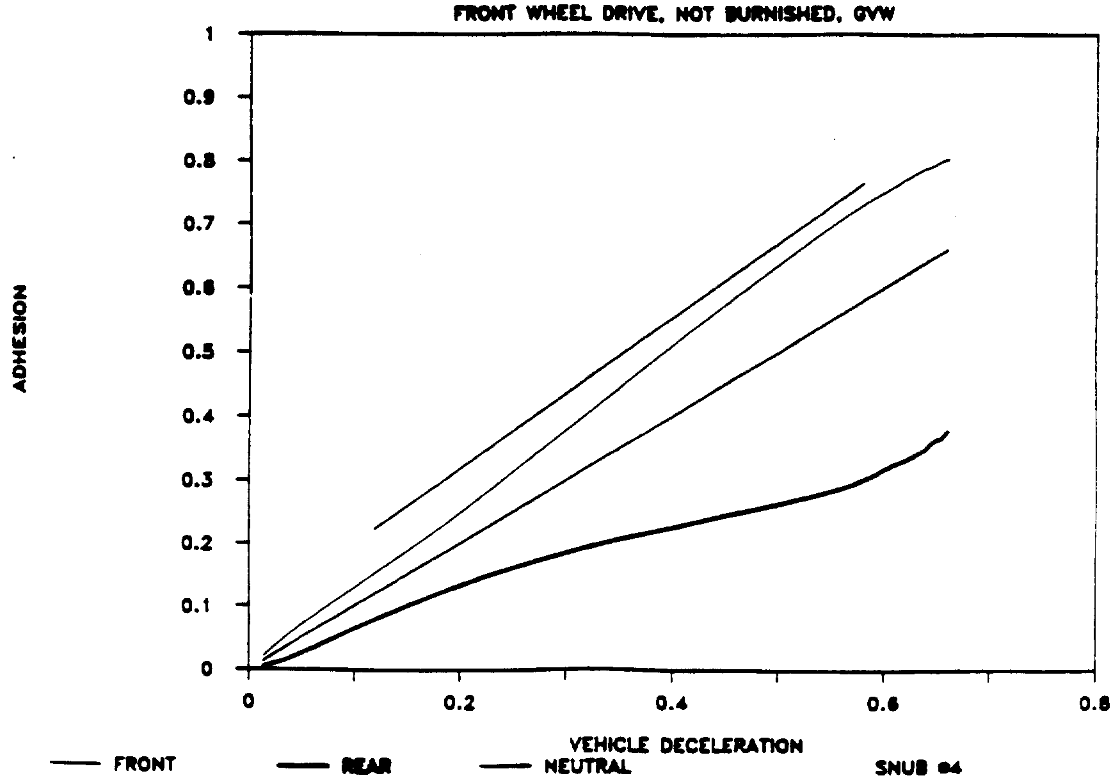


FIG. 31

135 EVALUATION, SINGLE AXLE METHOD

FRONT WHEEL DRIVE, BURNISHED, LVW

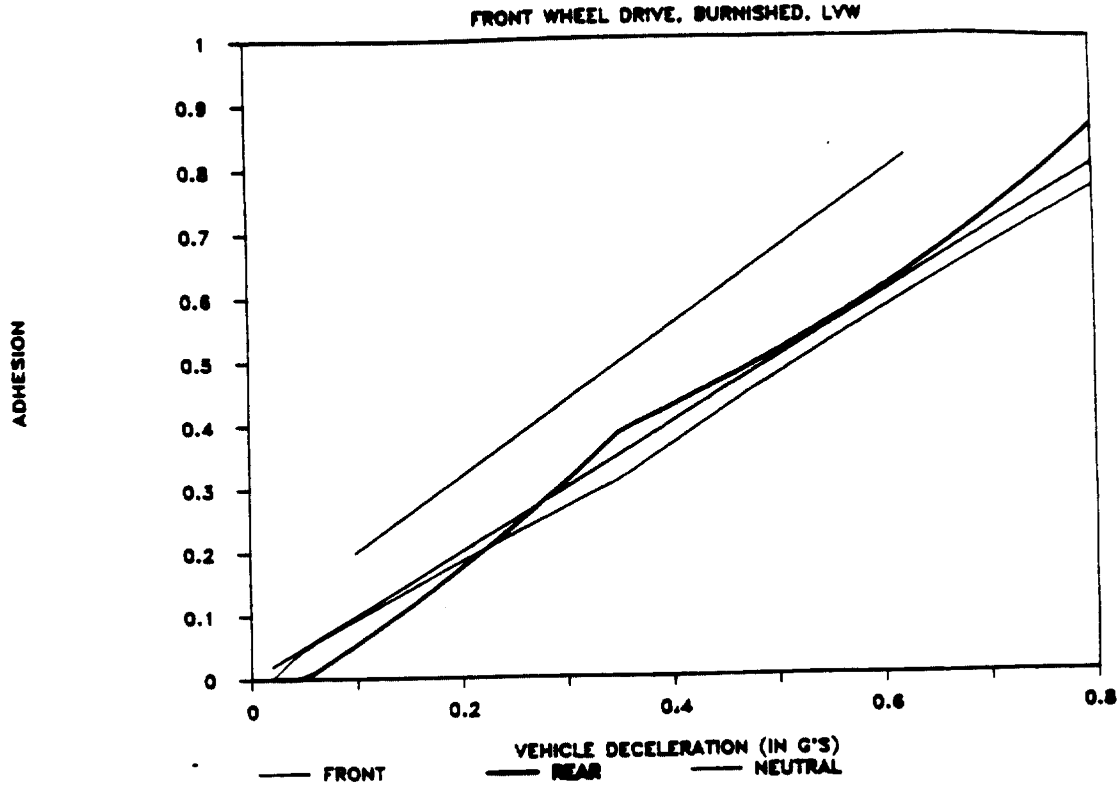


FIG. 32

135 EVALUATION, SNUBS W/ TORQUE WHEELS

FRONT WHEEL DRIVE, BURNISHED, LVW

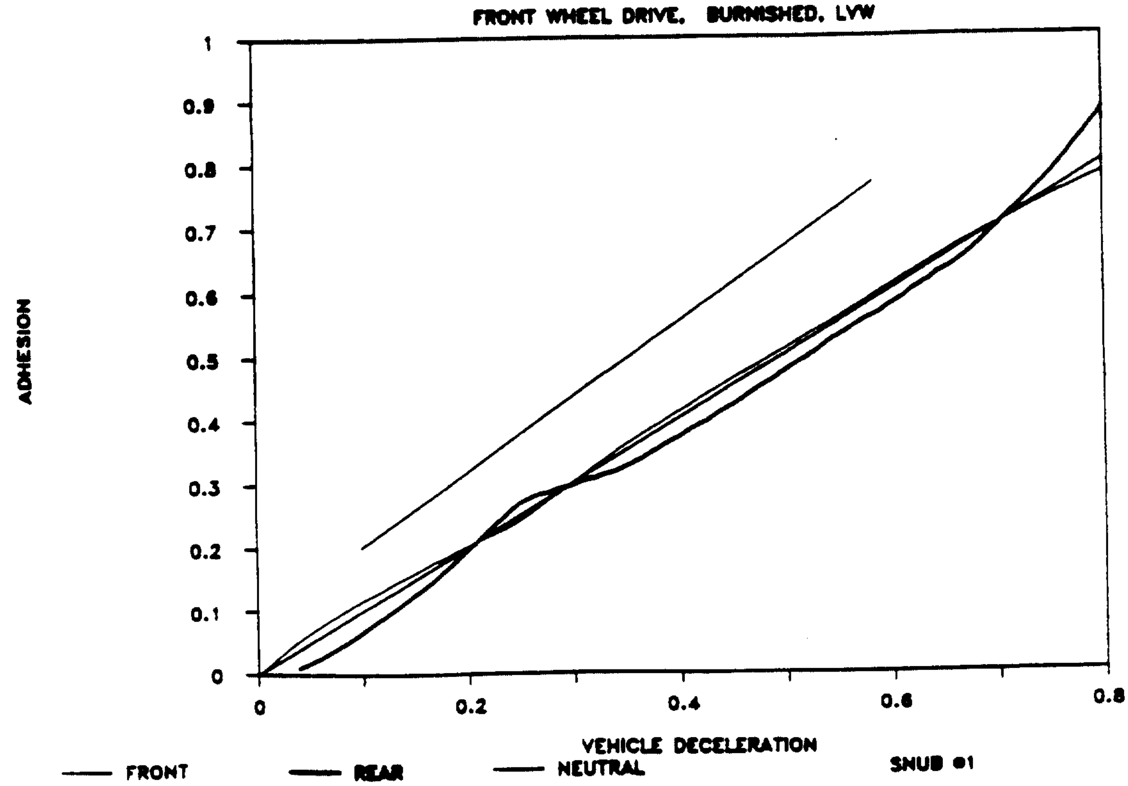


FIG. 33

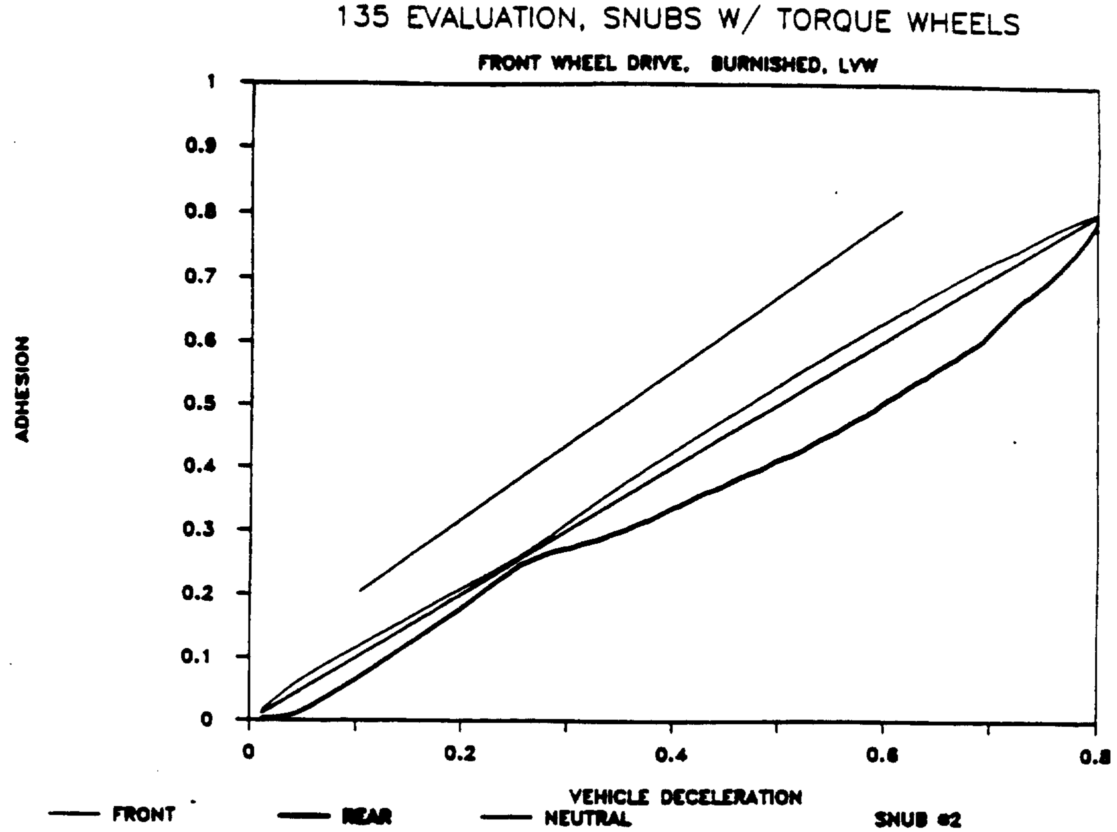

135 EVALUATION, SNUBS W/ TORQUE WHEELS
FRONT WHEEL DRIVE, BURNISHED, LVW
ADHESION
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
VEHICLE DECELERATION
FRONT
REAR
NEUTRAL
SNUB #2

FIG. 34

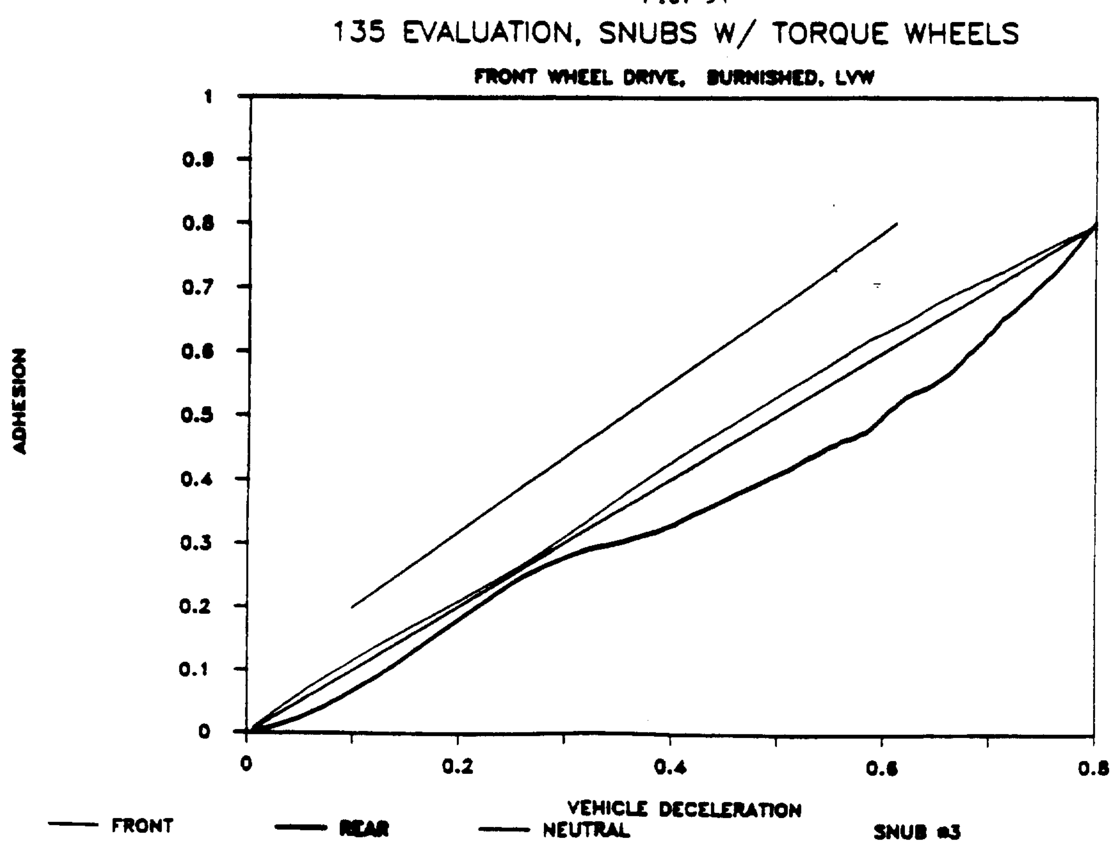

135 EVALUATION, SNUBS W/ TORQUE WHEELS
FRONT WHEEL DRIVE, BURNISHED, LVW
ADHESION
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
VEHICLE DECELERATION
FRONT
REAR
NEUTRAL
SNUB #3

FIG. 35

135 EVALUATION, SNUBS W/ TORQUE WHEELS

FRONT WHEEL DRIVE. BURNISHED. LVW

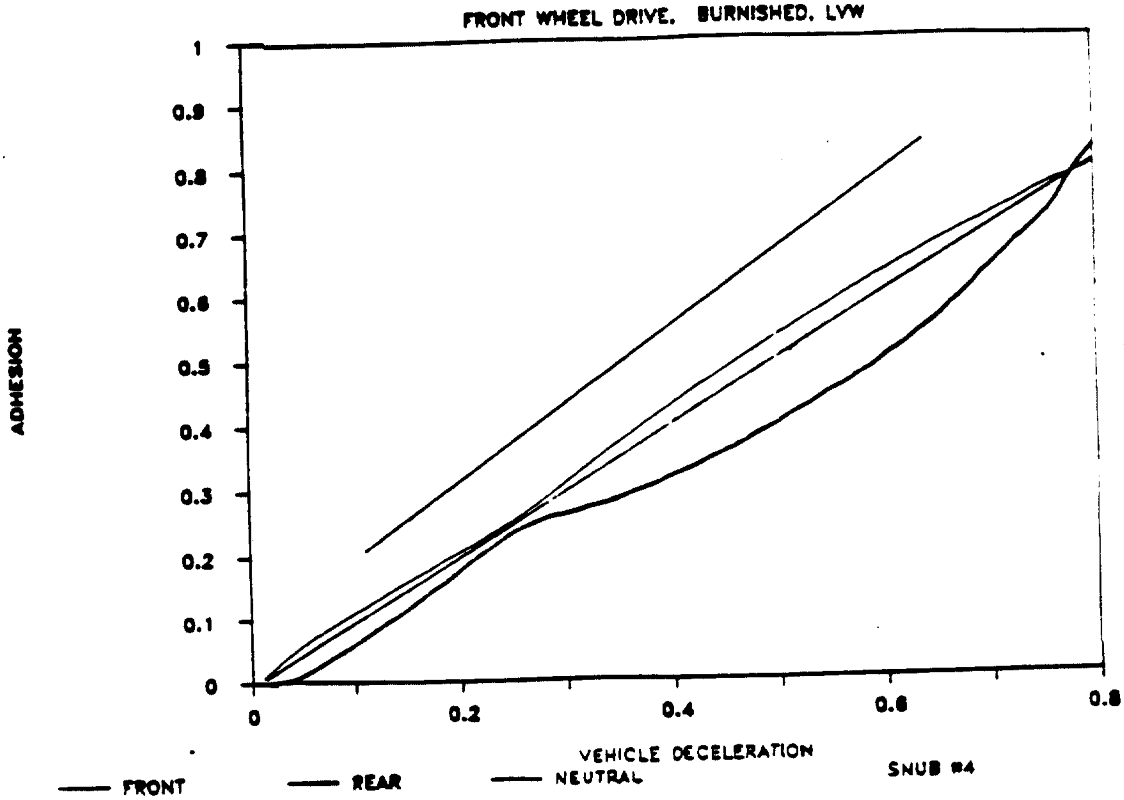


FIG. 36

135 EVALUATION, SINGLE AXLE METHOD

FRONT WHEEL DRIVE, BURNISHED, GVW

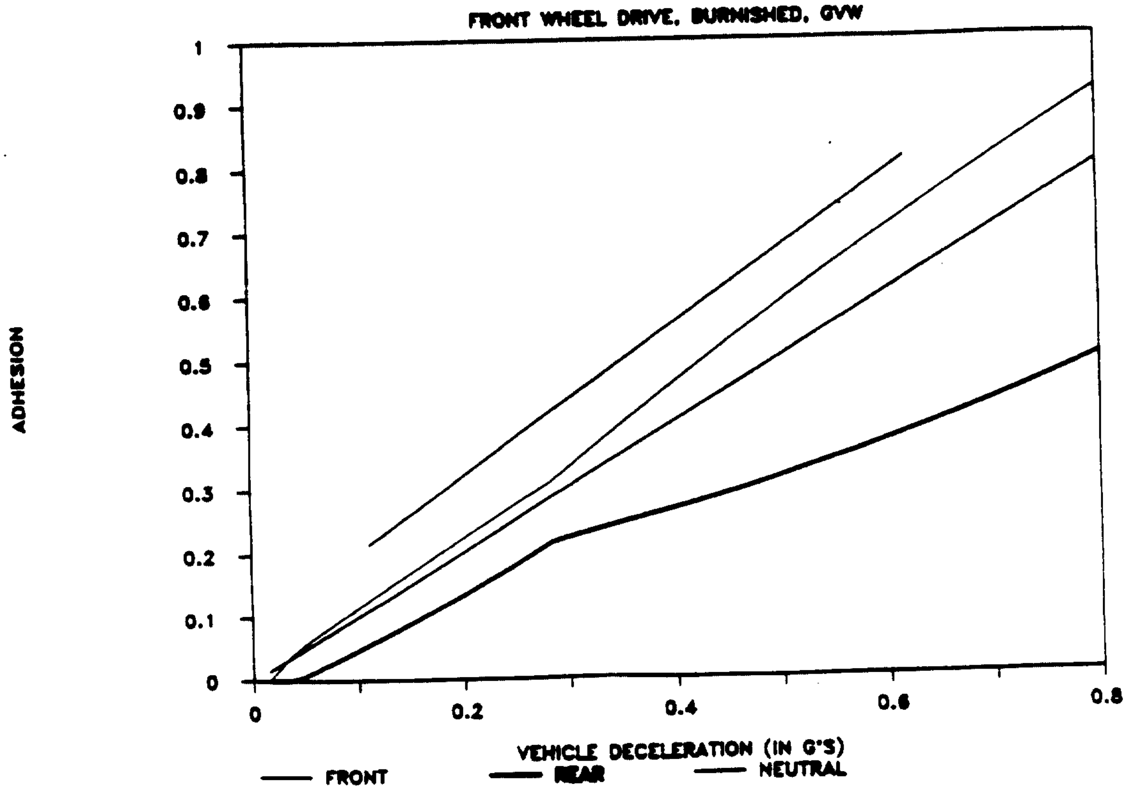


FIG. 37

135 EVALUATION, SNUBS W/ TORQUE WHEELS

FRONT WHEEL DRIVE, BURNISHED, GVW

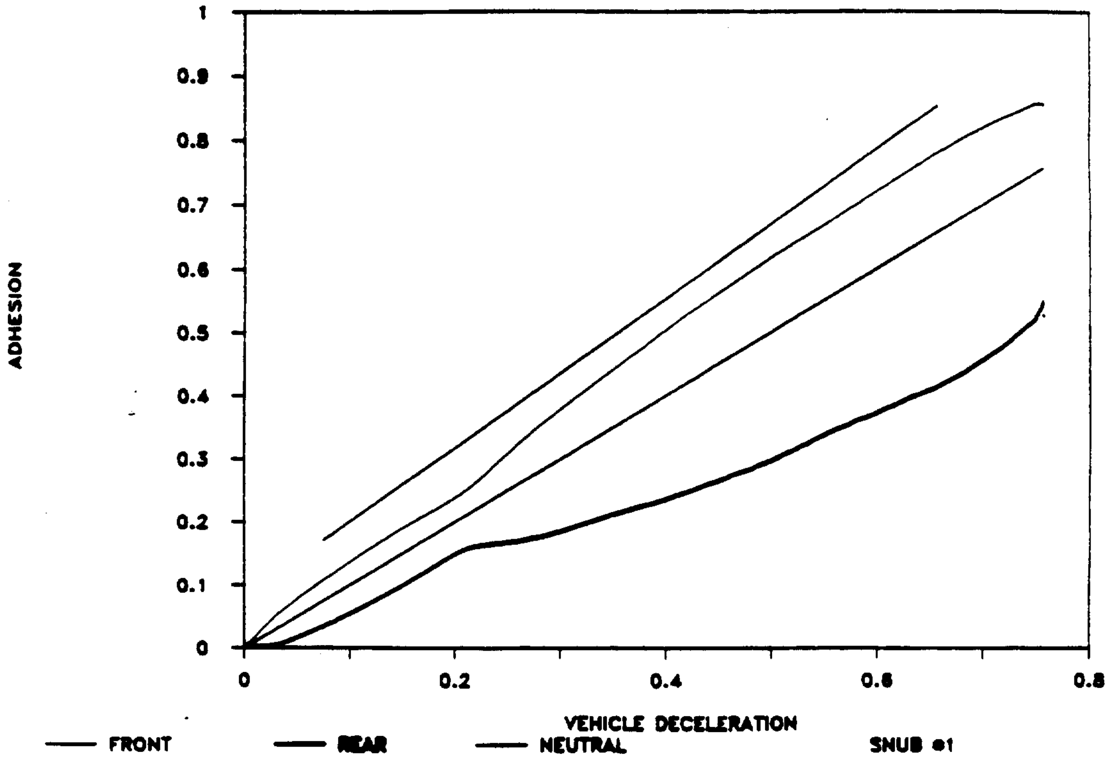


FIG. 38

135 EVALUATION, SNUBS W/ TORQUE WHEELS

FRONT WHEEL DRIVE, BURNISHED, GVW

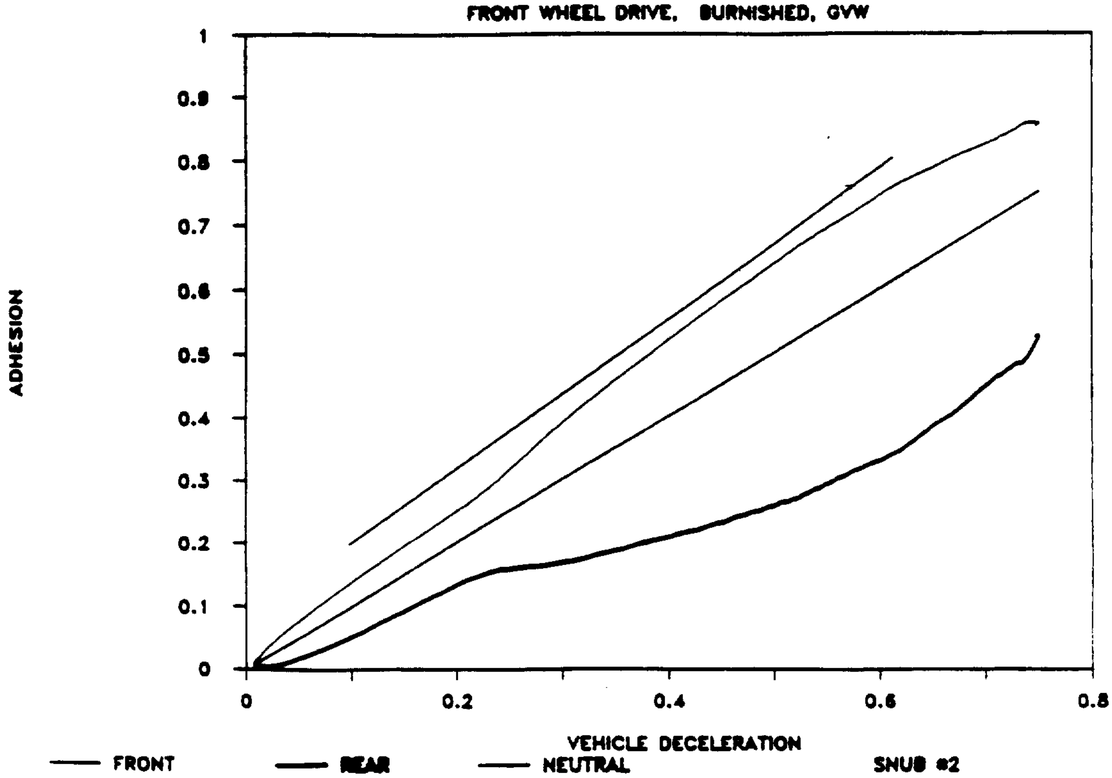


FIG. 39

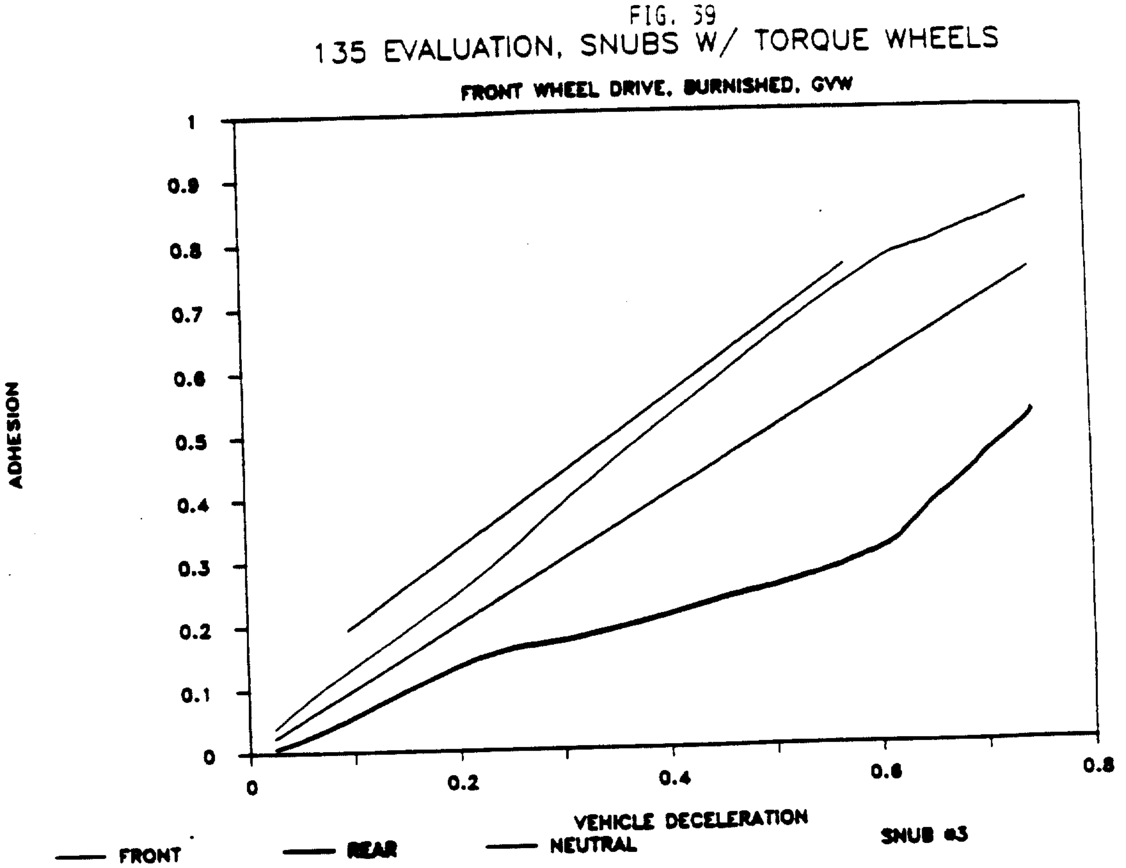

135 EVALUATION, SNUBS W/ TORQUE WHEELS
FRONT WHEEL DRIVE, BURNISHED, GVW
ADHESION
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
VEHICLE DECELERATION
FRONT
REAR
NEUTRAL
SNUB #3

FIG. 40

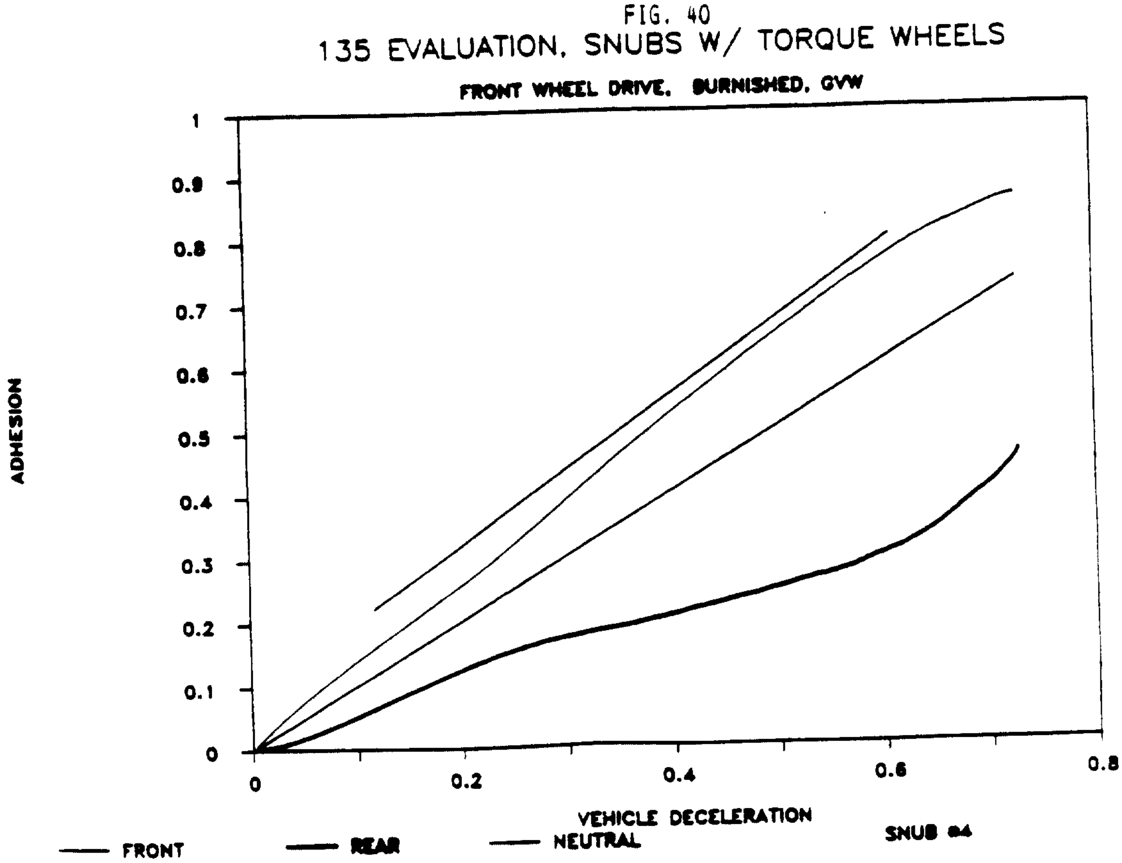

135 EVALUATION, SNUBS W/ TORQUE WHEELS
FRONT WHEEL DRIVE, BURNISHED, GVW
ADHESION
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
VEHICLE DECELERATION
FRONT
REAR
NEUTRAL
SNUB #4

FIG. 41

135 EVALUATION, RTP TEST

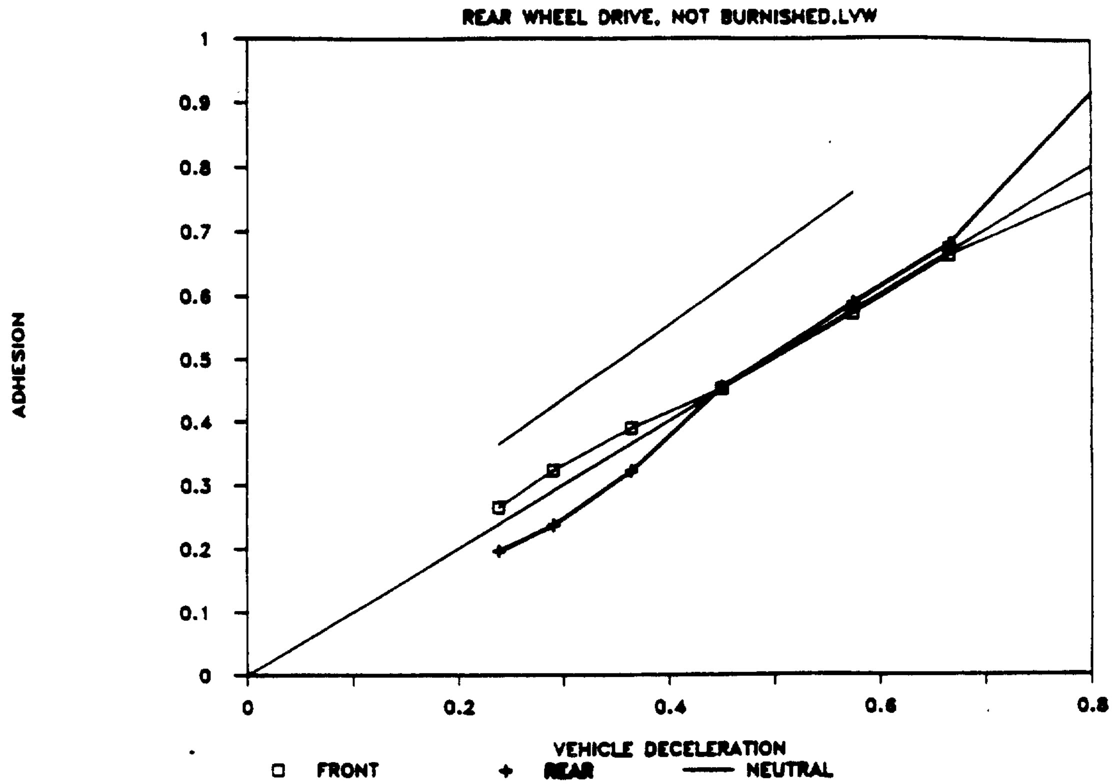


FIG. 42

135 EVALUATION, RTP TEST

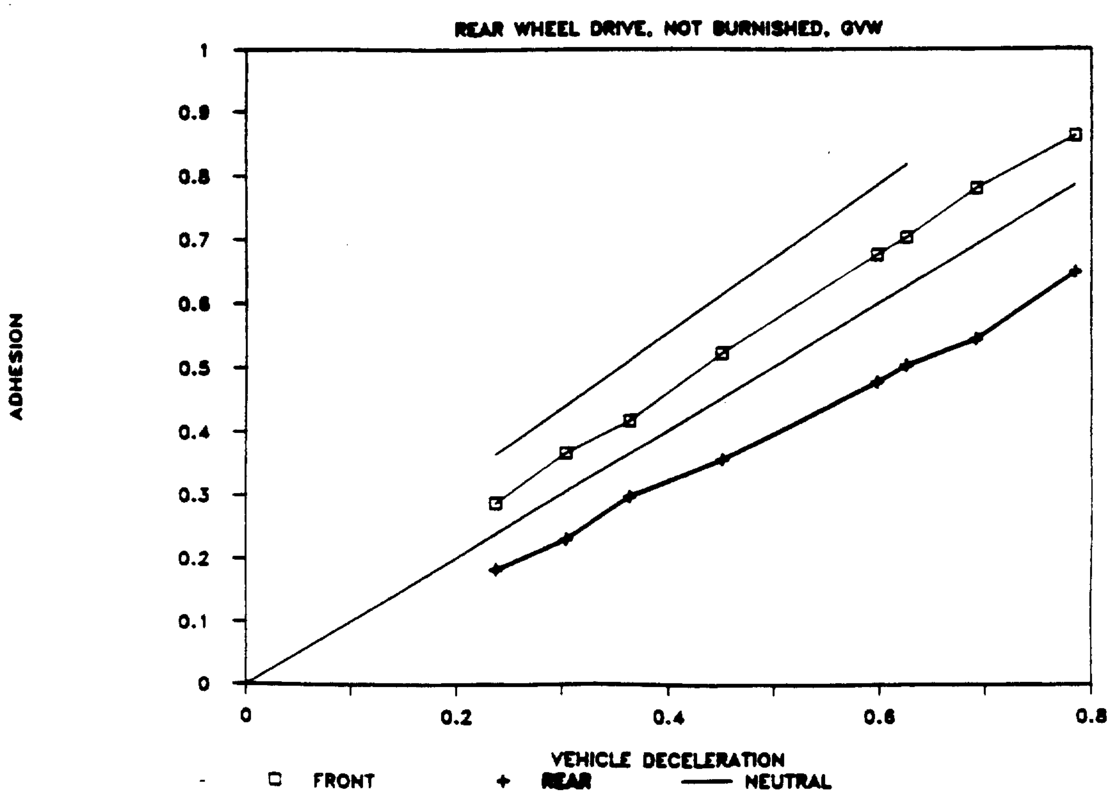


FIG. 43

135 EVALUATION, RTP TEST

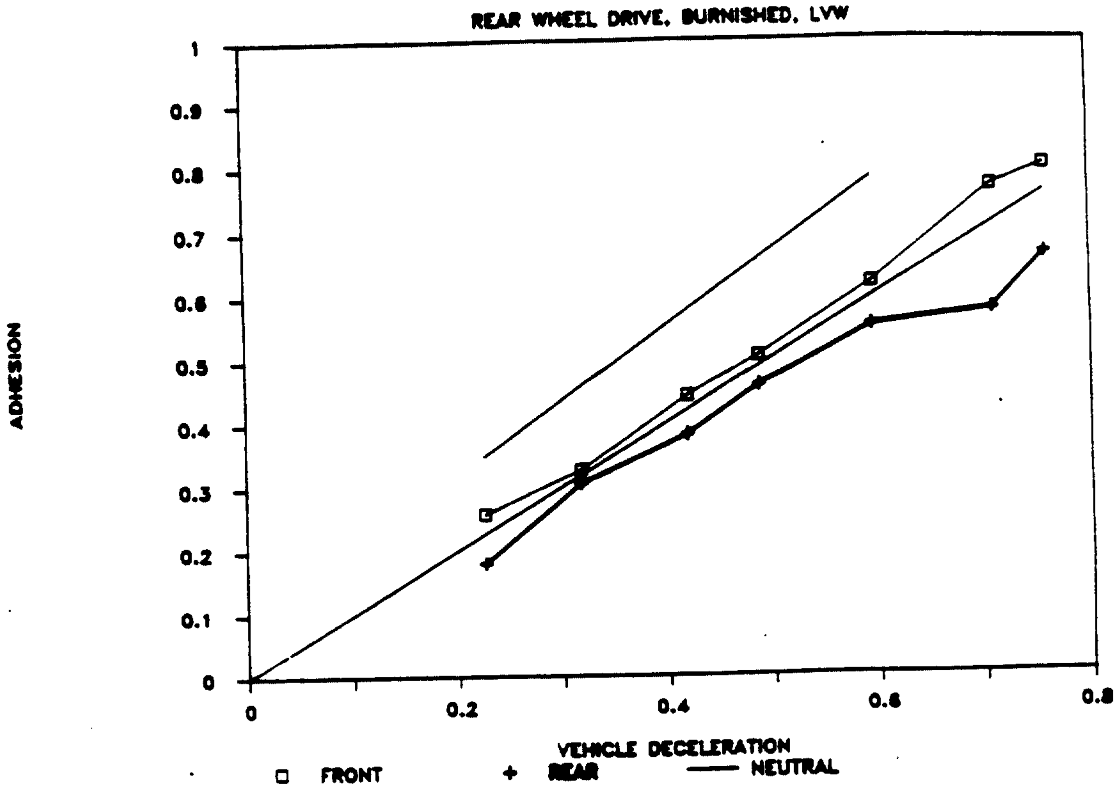


FIG. 44

135 EVALUATION, RTP TEST

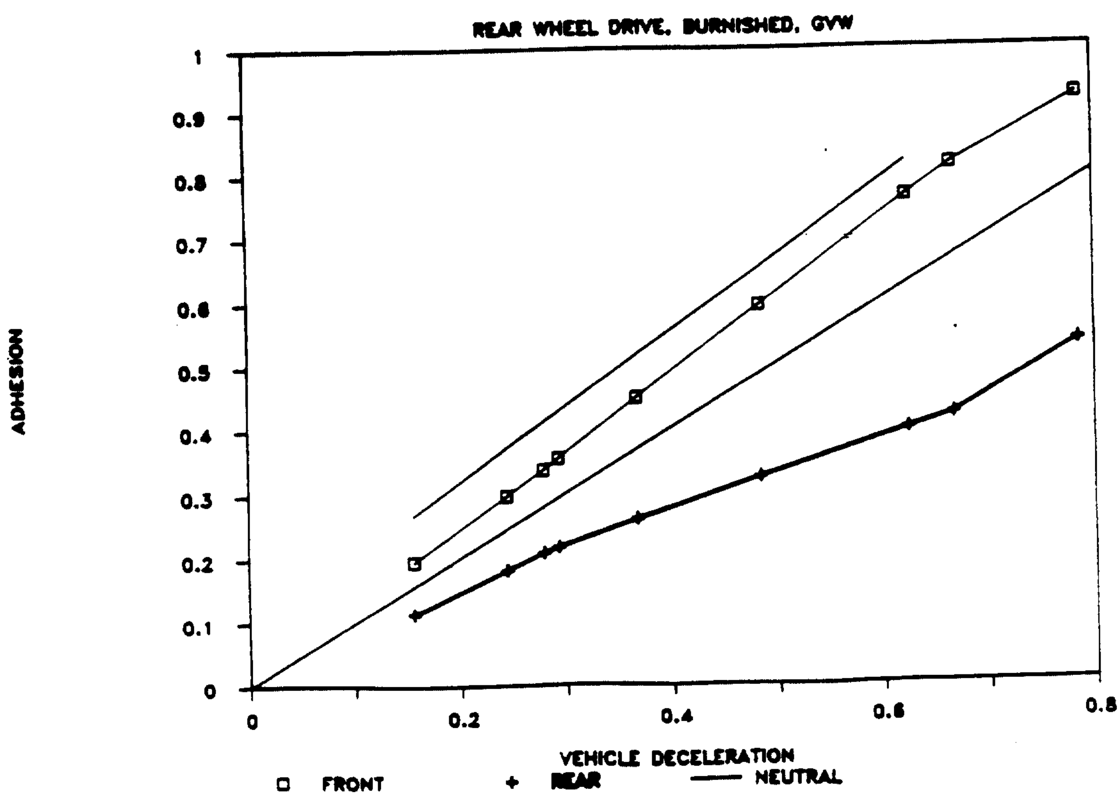


FIG. 45

135 EVALUATION, RTP TEST

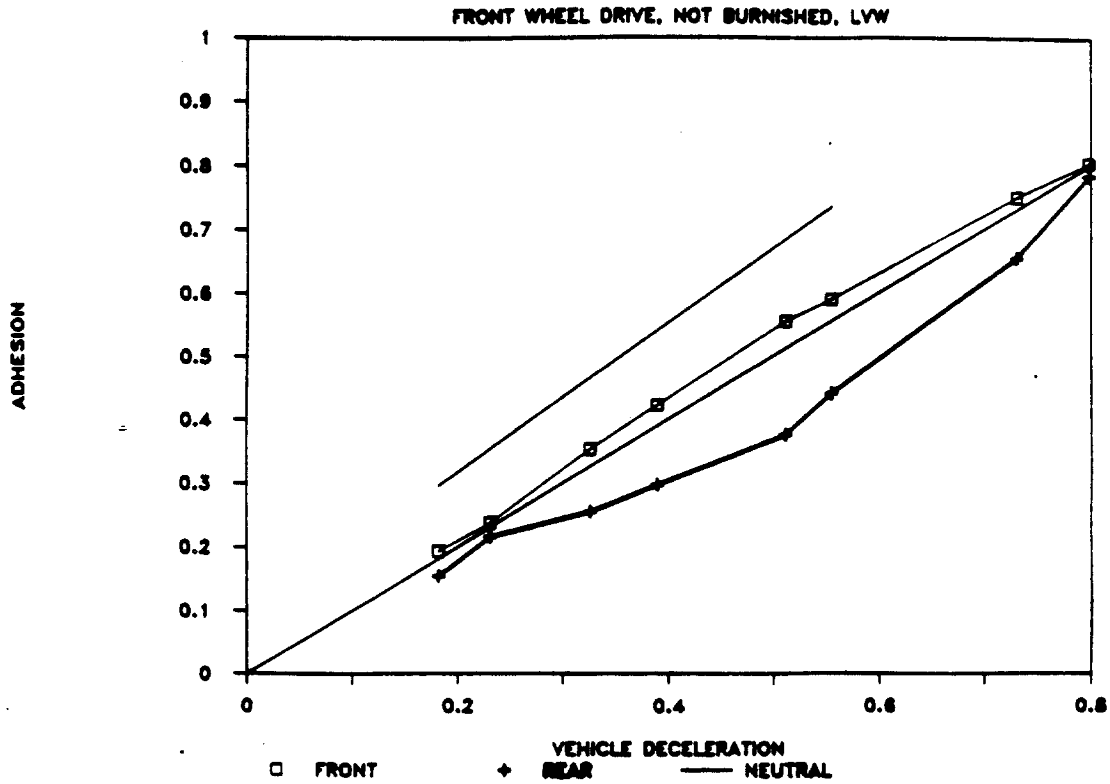


FIG. 46

135 EVALUATION, RTP TEST

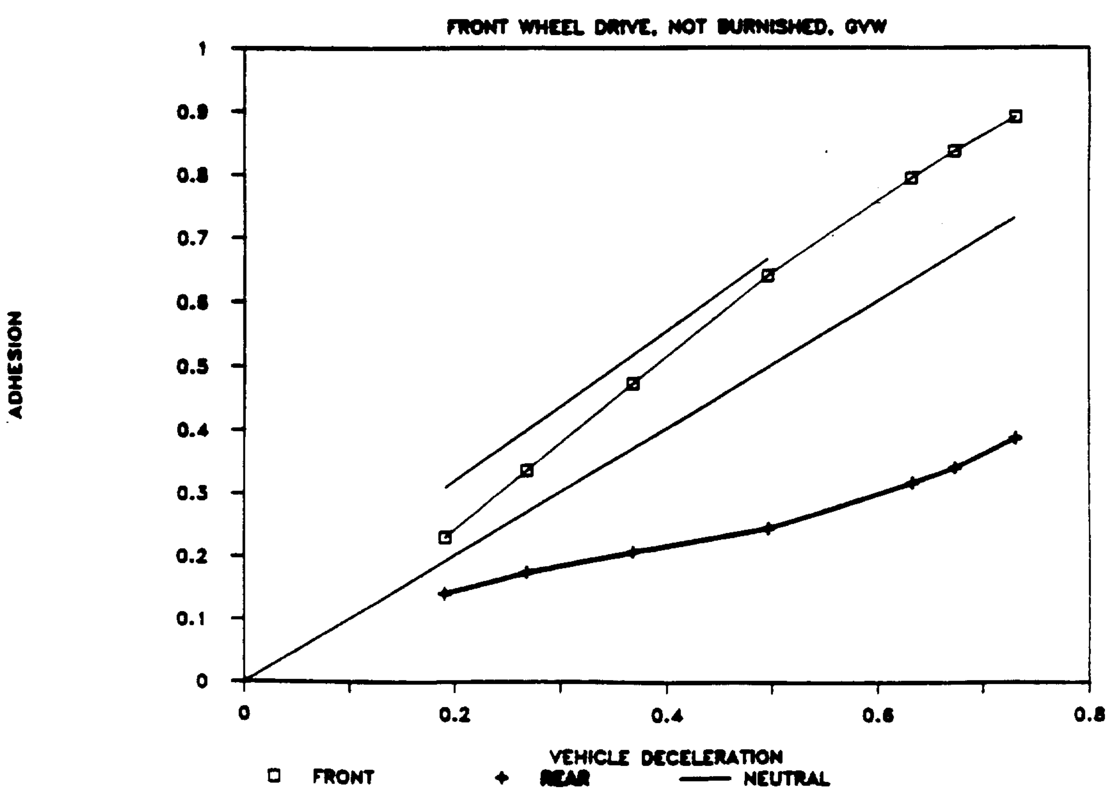


FIG. 47

135 EVALUATION, RTP TEST

FRONT WHEEL DRIVE, BURNISHED, LVW

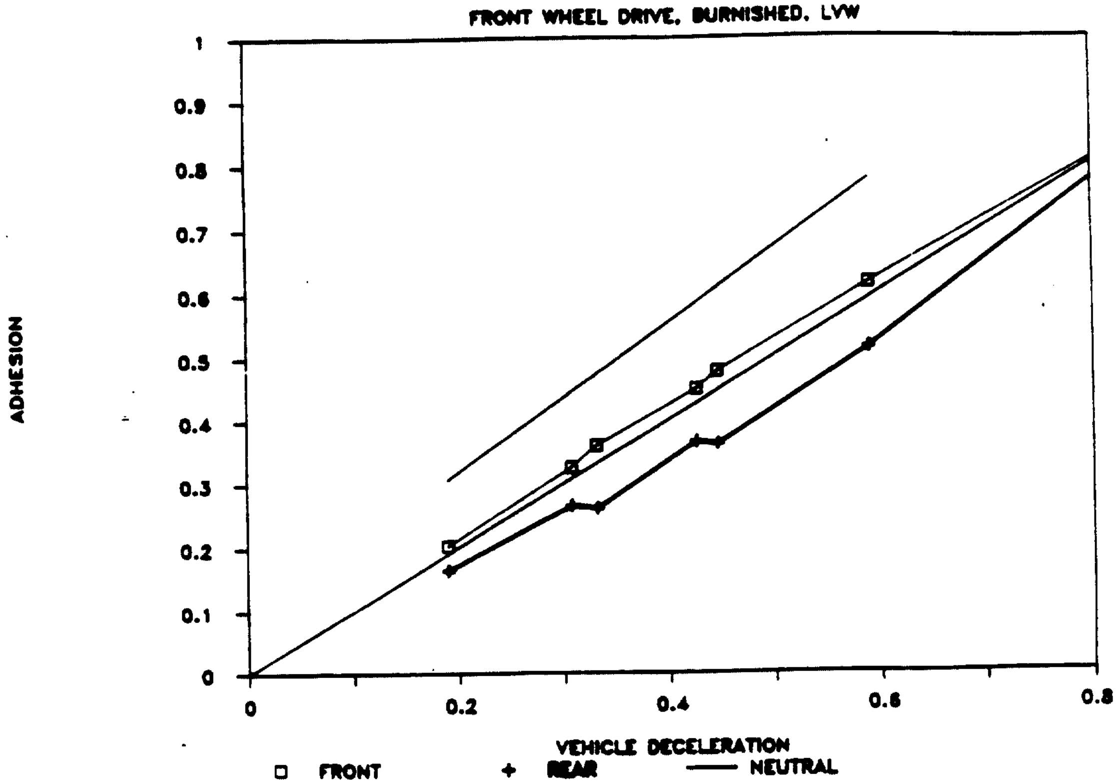


FIG. 48

135 EVALUATION, RTP TEST

FRONT WHEEL DRIVE, BURNISHED, GVW

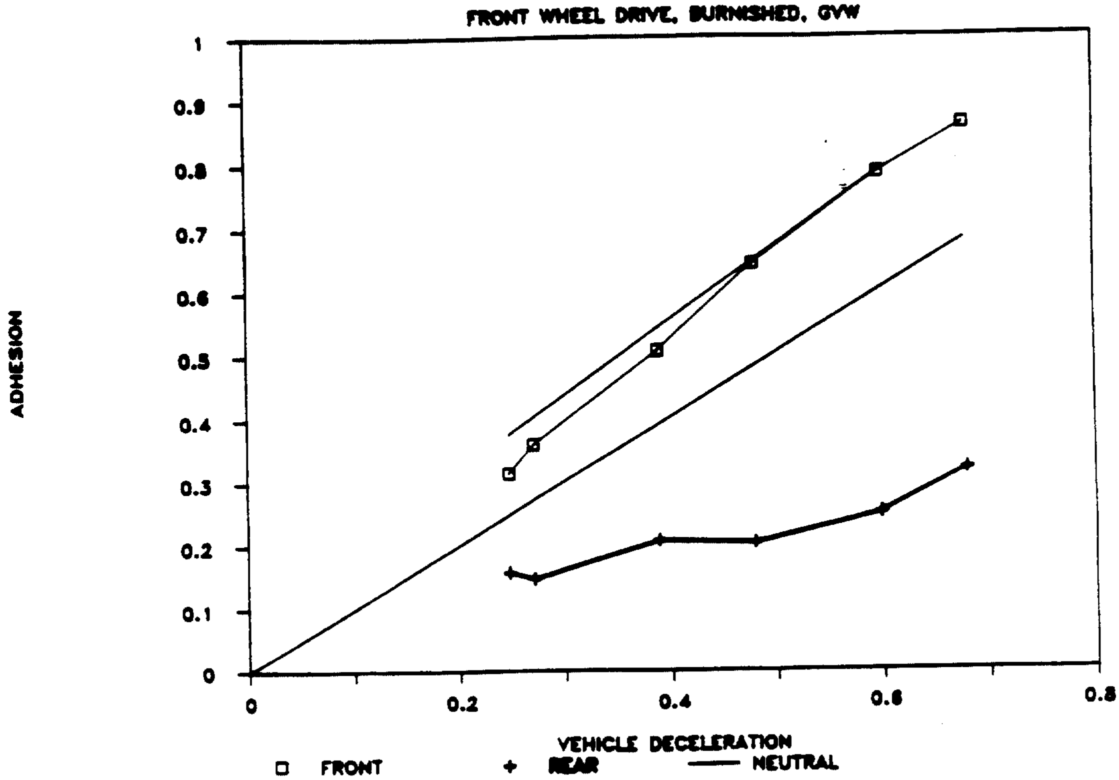


FIG. 49

135 HARMONIZATION TESTING

RTP TEST DATA 4TH RUN (BLUE GROUP)

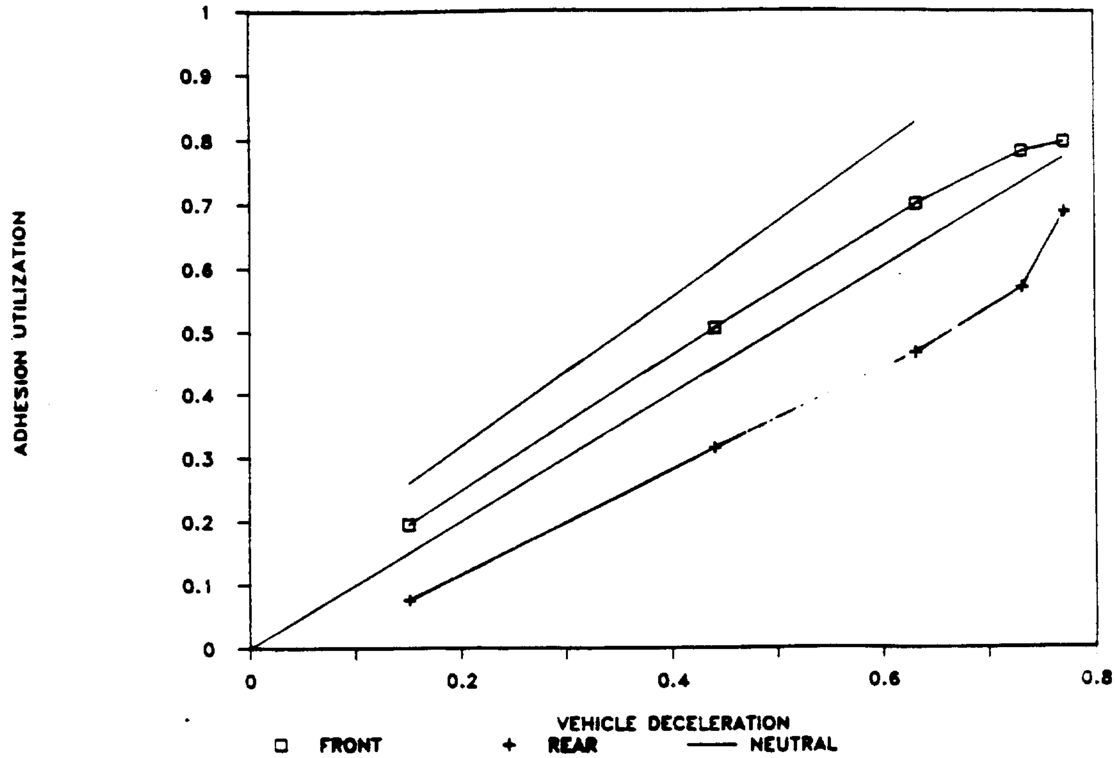


FIG. 50

135 HARMONIZATION TESTING

RTP TEST DATA 2ND RUN (ORANGE GROUP)

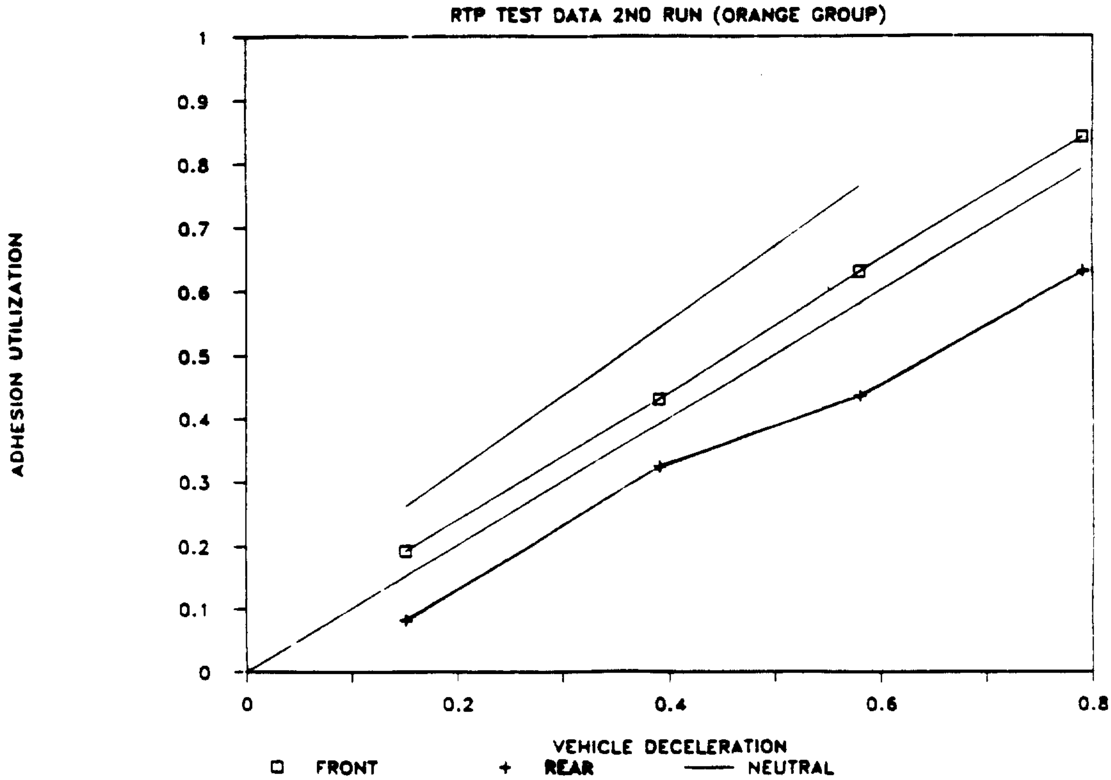


FIG. 51

135 HARMONIZATION TESTING

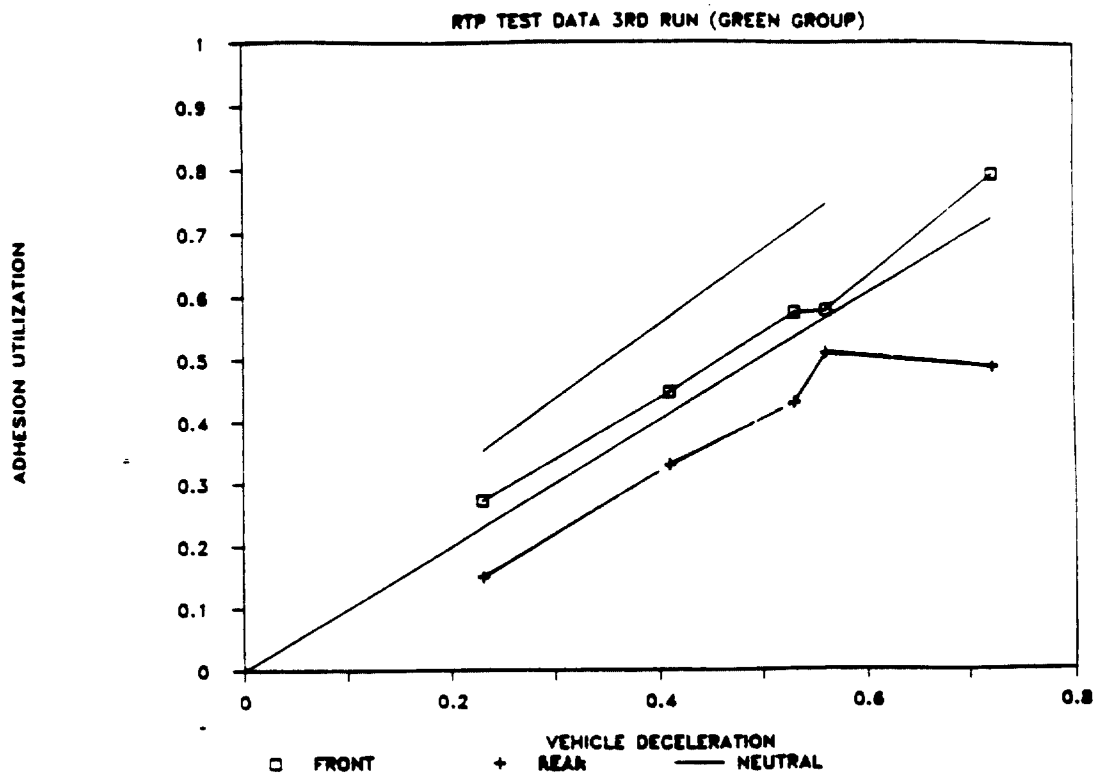
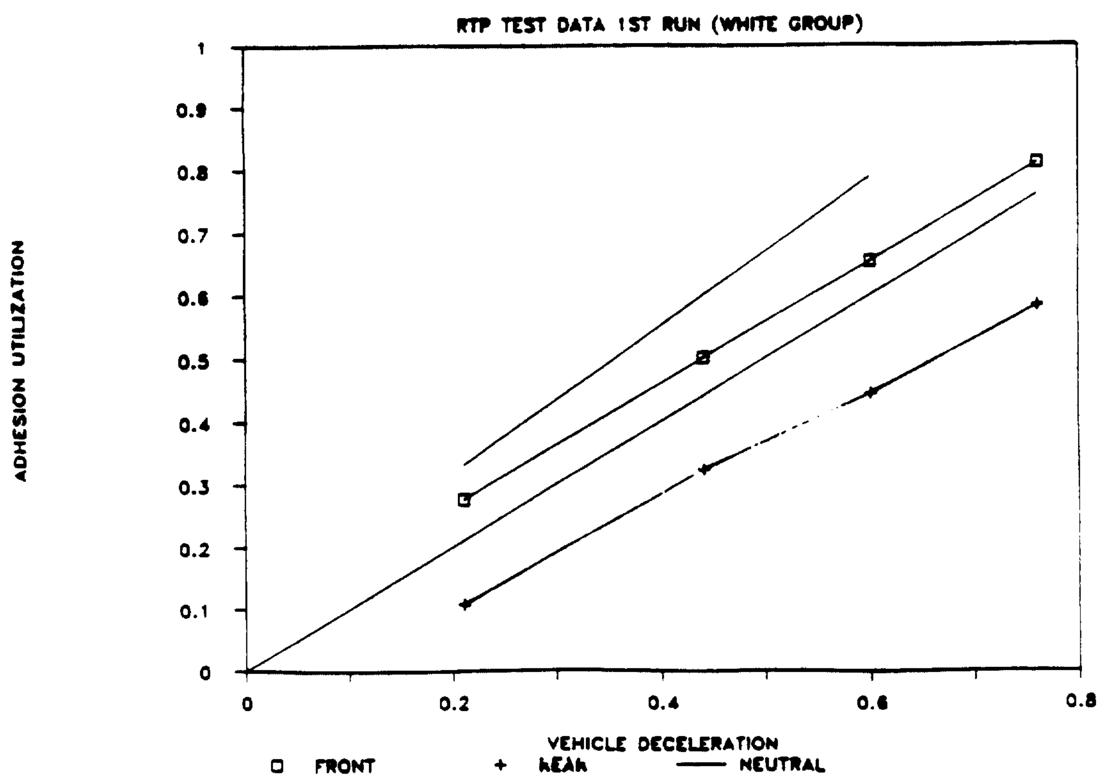


FIG. 52

135 HARMONIZATION TESTING



NHTSA TESTS

OBJECTIVE

The purpose of this Appendix is to review the results of the NHTSA vehicle test program which are used as the basis for establishing performance criteria contained in the proposed FMVSS 135.

CONCLUSIONS

1. The results obtained by the NHTSA in its vehicle test program are not a suitable basis for determining brake system performance criteria for FMVSS 135.

2. The test procedures used for the NHTSA tests show that no vehicles were tested to the complete procedure prescribed in FMVSS 135.

3. The agency's test results regarding the effects of the burnishing procedures on brake system performance, both stopping distance and brake balance, are consistent with the results of the GM test program.

4. The failure to equip vehicles with new tires at the start of each NHTSA test seriously limits the validity of the stopping distances measured in these tests.

5. Stopping distances measured on vehicles containing any degree of rear bias, which is specifically precluded by the proposed standard, are not a valid basis for determining stopping distance criteria in FMVSS 135. This limitation applies to both the NHTSA and GM test programs.

6. Averaging results for each performance test over a broad range

of vehicle configurations, sizes, and weights is an invalid analysis method and cannot be used to predict appropriate FMVSS 135 performance limits.

7. Any vehicle which fails a single performance requirement in an FMVSS brake test fails to comply with the standard. Therefore it is inappropriate to extrapolate any of that vehicle's test results to establish performance requirements because of the interdependence of all aspects of vehicle brake performance.

8. Any vehicle which meets a single performance requirement with a pedal effort within 5% of the maximum allowed would require careful review and further analysis on the part of a manufacturer in a self certification protocol.

9. The NHTSA's test results on fade and recovery performance using various heating cycles generally support the findings and recommendations of the GM testing and analysis described in Appendix 8, GM Test Program.

RECOMMENDATIONS

1. The agency should re-evaluate the methods used to establish performance criteria in FMVSS 135 on the basis of its own test data, this review of the NHTSA test program, and the inherent tradeoffs in brake system performance discussed in this GM response.

2. The agency should conduct additional vehicle tests to the complete test procedure of the proposed FMVSS 135 to serve as a performance database for further review and analysis in subsequent discussion of harmonized brake standards.

DISCUSSION

The NHTSA has conducted an extensive vehicle test program to assess performance capabilities of various vehicles in several iterations of the proposed harmonized brake standard. In cooperation with vehicle manufacturers and the GRRF, a number of specific test issues have been studied including the response of vehicle brake systems to burnish and various fade and recovery procedures. This extensive test program has been conducted over a period of several years in parallel with the evolution of R.88. The evolution of the recommended test procedure has unfortunately limited the usefulness of some early test results in predicting vehicle performance capability in the FMVSS 135 test.

The NHTSA vehicle test program includes a total of 62 separate tests of 39 passenger cars and additional tests of 6 multipurpose vehicles. For this review, the test results for the 6 multipurpose vehicles were discarded because the proposed standard is applicable to only passenger cars. The vehicle information including VIN, test weights, dimensions, and brake system characteristics are listed in Table 1.

The stopping distances and pedal efforts measured in these 62 vehicle tests are included in four separate NHTSA reports. Because the vehicle test procedure was evolving during a series of international meetings, the results measured during the four phases of the test program are not directly comparable, as is noted in several portions of the NHTSA documents. The various test procedures employed, as GM understands them, are compared in Table 2. In some cases, the procedural changes are small, and in others, the distinctions are more dramatic, and likely to produce substantially different results in the same vehicle when tested to the proposed FMVSS 135 test procedure. In particular, the various fade heating cycles used, and the presence or absence of burnish are two notable distinctions among the test procedures.

For purposes of analysis, GM has constructed a summary of the NHTSA test results which is shown in Table 3. The criteria used for evaluating the NHTSA vehicle test results are identical to those used for evaluating the results of the GM test program. The stopping distances and pedal efforts shown in Table 3 were also used for subsequent evaluation.

Two important factors regarding analysis of the brake test results should be noted prior to discussion of the GM review and conclusions. First, NHTSA test reports indicate that tires were replaced prior to test if necessary. "Like new" or "full tread depth" tires were used. We assume this means that many of the NHTSA tests were not run with new tires. This conclusion is consistant with our analysis of stopping distances, from which we derived tire-road coefficients representative of used tires. As shown in Appendix 6, Tire to Road Coefficients, the stopping distance performance varies with the level of tire-road peak coefficient. Further, Appendix 11, Tire Burnish, shows the peak tire-road coefficient of friction increases rather quickly from a new condition to a burnished state and continues to increase as the tire is used. Therefore, the absence of installation of new tires at the beginning of test sequence in the NHTSA tests would make the results completely invalid for other than comparative purposes. In typical GM certification tests, new tires and brakes are installed, and the vehicle is driven to the test road without any use of the brakes prior to testing.

The second important factor is that when a vehicle fails to meet a particular part of the test requirement, it should constitute a failure of the entire test. For example, exceeding a pedal force limit by only a few pounds for a very brief period of time may indeed make no significant difference in the total stopping distance of the vehicle, but it constitutes a failure to meet that particular requirement of the proposed FMVSS 135.

The GM analysis of the NHTSA test program has closely examined vehicle performance with respect to the stopping distances measured, the pedal efforts used, the brake balance from either an agency evaluation or by inference from stopping distances (described later), and the performance during the hot stop tests. Based on this analysis, a vehicle by vehicle summary of test results where the vehicle has either failed or marginally met the performance requirements, has been constructed and is included in Table 4. This analysis indicates that all but two of the 39 vehicles failed to meet all of the test requirements of FMVSS 135. General Motors has considered vehicles exhibiting inconsistent pass/fail performance in consecutive tests as not complying with FMVSS 135. It is questionable if the two vehicles, Dodge Colt and Honda Civic, which were tested according to the first harmonized procedure would have passed if they were tested to the proposed FMVSS 135 procedure. The basis for questioning the results is that the first harmonized procedure did not contain a burnish provision and, therefore, the best cold effectiveness stop after burnish would have very likely required significantly lower pedal efforts than those used in the unburnished condition. In the hot stop requirements of FMVSS 135, the maximum permissible pedal effort during the test is limited to the average in the best burnished brake performance stop, and therefore, both the Dodge Colt and the Honda Civic would have likely failed the hot stop requirement at the lower level of pedal effort. In any case, the proper interpretation of the NHTSA's test program results is that contrary to the agency position that no increase in stringency is reflected in FMVSS 135, virtually all the vehicles tested by the NHTSA have been shown to fail one or more of the requirements of FMVSS 135.

Based on this review, the agency's position that the current vehicle fleet can meet the requirements of FMVSS 135 with, at most, a minor proportioning valve change is clearly unsupported by its own data. As Appendix 4, Brake Balance Influence on Stopping Distance, clearly shows, the minor proportioning valve change suggested by the agency could only increase laden stopping distances and precipitate additional test requirement failures. When this change is coupled with a required installation of new, green tires to the test vehicle, the likelihood of vehicles meeting the laden pre-burnished requirements of FMVSS 135 is remote, at best.

The GM analysis of NHTSA test results and comments regarding whether these vehicles meet the front bias requirement or not, are based on the analysis of the calculated brake balance using the stopping distance results and certain assumptions as follows. The first is that the vehicle center of gravity heights are typical of those GM has measured for similar configurations. For purposes of calculation, the values of 21 inches for the unladen condition and 20 inches for the laden condition were used. The second assumption needed is that the vehicles have a 0.60 second brake system reaction time in all stops. Given this assumption, a measured vehicle stopping distance and speed can be converted to a deceleration rate. The final assumption needed is a limit on tire to road peak coefficient. Given that the tires were not new, a value of 1.0 was selected and used in all the subsequent analysis. This assumption tends to increase the range of potential brake balance that would be consistent with the stopping distances the agency measured.

Given these assumptions, a laden vehicle stopping distance can be used to determine a minimum fraction rear brake consistent with the tire coefficient and stopping distance. Likewise, an unladen vehicle stopping distance can be used to determine a maximum fraction rear brake consistent with the tire coefficient assumption. For all 62 vehicle tests conducted by the agency, these upper and lower bounds on brake balance have been plotted on the unladen fishbone diagram for each vehicle. The results of this analysis for each vehicle test are shown in Figures 1-62 with the range of rear biased brake balance highlighted with cross hatch. While this analysis typically overestimates the degree of both front and rear bias, i.e., sets the maximum window in brake balance, it shows that many of the vehicles have some degree of rear bias in these tests. Further, the agency's own adhesion utilization procedure shows that 11 of the 31 vehicles tested for brake balance did not meet the brake balance requirements of FMVSS 135. One interesting anomaly in this GM analysis of brake balance on NHTSA test vehicles is the Plymouth Horizon (NHTSA Test Report 3) where the laden and unladen stopping distances were not consistent with a positive window, but rather produced a minimum rear brake fraction in the laden condition that was greater than the maximum permitted in the unladen condition. Clearly, the test values reported for this vehicle are inconsistent.

Two comparative studies conducted by the agency during its vehicle test program are of interest and merit discussion. The first is the study of laden pre-burnished stopping distance vs laden burnished stopping distance. The test results generally show that laden vehicle stopping distances are increased after burnish. Absent new tire installation, this is precisely the effect one would predict on the basis of GM's study of burnish effects in brakes where the laden vehicle is more front biased with burnished brakes than with green brakes and therefore capable of a lower deceleration rate which inevitably results in a longer stopping distance. This is entirely consistent with the findings described in the Appendix 10, Brake Burnish.

The second comparative study is related to the temperatures generated in brakes when tested to various fade heating cycles. Comparing the front brake temperatures at the end of fade heating cycle, the R.88 fade procedure generally generates lower temperature than the FMVSS 105 first fade procedure. This is consistent with the GM test results. Further, absolute values of temperature vary considerably from vehicle to vehicle, which is precisely the reasons for ignoring peak temperature as a basis for evaluating fade heating cycles, as noted in Appendix 25, Fade heating Cycle. Because the fade heating cycle of R.88 is run at constant pedal force rather than constant deceleration, as proposed in FMVSS 135, the rear brake temperature comparisons, Figures 64 and 66, are inappropriate.

In evaluations of the modified R.88 heating cycle (30 seconds interval and constant pedal force), the front and rear brake temperatures achieved are generally higher than those developed in FMVSS 105 (see Figure 65), and therefore, should be discarded as a viable replacement. Agency assessments of the alternative 1 fade heating cycle in FMVSS 135 also show higher temperatures than either FMVSS 105 or alternative 2, see Figures 67 and 68, making this lengthy alternative 1 fade heating cycle even more unrealistic. This trend in severity is consistent with the GM temperature tests, and the variability in peak temperature among the vehicles continues to support the GM recommendation that either the fade heating cycle of R.88 or a modified alternative 2 procedure using longer interval between stops should be adopted.

General Motors believes that the results of the NHTSA test program cannot be used as a basis for establishing performance requirements in FMVSS 135 for the following reasons. The first reason is that the most of the vehicles in the NHTSA test program were rear biased, a condition which is specifically precluded by the proposed standard and is known to affect the stopping distance performance.

Second, the test procedures utilized differ from those specifically identified in the proposed standard. The GM vehicle tests clearly show that both vehicle brake balance and tire peak traction coefficient are changing throughout the FMVSS 135 and FMVSS 105 tests, and direct comparisons are inappropriate.

Third, the agency's attempts to use the its data base to establish performance criteria is inappropriate in that, absent new tire installations, the stopping distances measured do not reflect the worst case condition. This characteristic of the vehicle test program will consistently produce stopping distances shorter than those produced with new tires.

The fourth reason the extrapolation of these results is inappropriate is that all but two of the vehicles failed to meet all the FMVSS 135 test criteria for stopping distances, pedal efforts, brake balance, and hot stop performance. The remaining two vehicles may or may not have successfully completed the hot stop requirement of FMVSS 135, but absent data regarding burnished brake performance, no conclusive position is possible. The high degree of interrelationship between brake system performance in various test stages makes it clear that a vehicle failing one particular test performance requirement cannot be used to construct an average performance measure in another part of the standard where it might have passed.

Finally, the agency's method of determining an average and standard deviation of performance based on a population of vehicles with varying capacities to meet FMVSS 105 and requiring varying changes to meet FMVSS 135 where this is even possible, creates a diverse data base so lacking in commonality as to be invalid for use in predicting the achievable FMVSS 135 performance.

Table 1, Page 1 of 7

MANUFACTURER	MODEL	REP NO.	VEHICLE IDENTIFICATION NUMBER	WHEEL BASE mm	WHEEL BASE in.	Vmax km/h	Vmax mph
CHEVROLET	Cavalier	1	--	--	--	169	105.0146
CHEVROLET	Celebrity	1	2G1AW19R1C1402377	2664	104.8819	169	105.0146
CHEVROLET	Citation #1	1	1G1AX6854B6229311	2664	104.8819	167	103.7718
CHEVROLET	Citation #2	1	1G1AX685XBT146032	2664	104.8819	167	103.7718
CHEVROLET	Citation #3	1	1G1AX6854B6291064	2664	104.8819	167	103.7718
CHRYSLER	Cordoba	1	SH22CAR126386	2863	112.7165	150	93.2082
DODGE	Colt	1	JB3BE342XBU601159	2300	90.5512	150	93.2082
DODGE	Diplomat Wgn	1	1B3BM39G3BG157421	2863	112.7165	152	94.4510
FORD	EXP	1	2FABP0125CX128377	2393	94.2126	162	100.6649
FORD	Mustang	1	0F02B141347	2550	100.3937	161	100.0435
HONDA	Civic	1	JHMSR3327C5002686	2250	88.5827	137	85.1302
MAZDA	RX-7	1	JM1FB3313C0615804	--	--	193	119.9279
MERCURY	Marquis Wgn	1	1MEBP87F4BZ602913	2903	114.2913	153	95.0724
NISSAN	Sentra	1	TN1HB1256CU012333	--	--	145	90.1013
OLDSMOBILE	Cruiser Wgn	1	1G3AP35Y7CX101127	2945	115.9449	169	105.0146
OLDSMOBILE	Toronado	1	3257NAE329420	2895	113.9764	146	90.7227
PLYMOUTH	Gran Fury	1	2P3BB26E7CR116159	2863	112.7165	146	90.7227
PLYMOUTH	Horizon	1	1P3BL18A1BD286584	2518	99.1339	147	91.3441
RENAULT	18i	1	VF1DB34AXC1220002	--	--	146	90.7227
TOYOTA	Cressida	1	JT2MX62E0C0035028	2645	104.1339	170	105.6360
TOYOTA	Starlet	1	JT2KP61G2B5539740	2300	90.5512	150	93.2082
VOLKSWAGEN	Rabbit	1	1VWAB0172BV109315	2400	94.4882	161	100.0435
VOLVO	244	1	YV1AX8449C3718493	2650	104.3307	180	111.8499
CHEVROLET	Citation#1w/B	1	1G1AX6854B6229311	2664	104.8819	167	103.7718
FORD	Mustang w/B	1	0F02B141347	2550	100.3937	161	100.0435
NISSAN	Sentra w/B	1	TN1HB1256CU012333	--	--	145	90.1013
OLDSMOBILE	Cruis Wgn w/B	1	1G3AP35Y7CX101127	2945	115.9449	169	105.0146
FORD	EXP/Escort	2	2FABP0125CX128377	2393	94.2126	162	100.6649
FORD	Granada/LTD	2	1FABP27B6CG158691	2679	105.4724	148	91.9655
NISSAN	Sentra	2	TN1HB1256CU012333	--	--	145	90.1013
PLYMOUTH	Horizon	2	1P3BL18A1BD286584	2518	99.1339	177	109.9857
BMW	735i	3	WBAFH810XD7867335	2794	110.0000	209	129.8701
CHEVROLET	Caprice Clas	3	2G1AN6993D1223954	2946	115.9843	162	100.6649
CHEVROLET	Cavalier	3	1G1AD69G9CC127028	2540	100.0000	169	105.0146
DODGE	600	3	1B3BE46C2DC185225	2616	102.9921	140	86.9943
FORD	Granada	3	1FABP26B8BG111761	2680	105.5118	160	99.4221
FORD	Tempo	3	2FABP21R2EB119435	2537	99.8819	172	106.8788
FORD	Thunderbird	3	FABP4634DH120510	2642	104.0157	168	104.3932
HONDA	Prelude	3	JHMAB5226DC011100	2490	98.0315	151	93.8296
ISUZU	Impulse	3	JABAR07A8D0900856	2413	95.0000	174	108.1215
MAZDA-TOYO-KOGYO	626D	3	JM1GC2213D1506896	2667	105.0000	168	104.3932
MITSUBISHI	Starion	3	JA3BC54H1E2500201	2436	95.9055	179	111.2285
MITSUBISHI	Tredia	3	JA3BF3646D2450934	2438	95.9843	161	100.0435
NISSAN	Pulsar	3	JN1MN23S1DM101674	2456	96.6929	150	93.2082
PLYMOUTH	Horizon	3	1P3BL18A1BD286584	2518	99.1339	177	109.9857
SUBARU	DL	3	JF1AM42B5DB444375	2456	96.6929	145	90.1013
TOYOTA	Camry	3	JT2SV12HXD0008687	2600	102.3622	180	111.8499
TOYOTA	Cressida	3	JT2MX62E0C0035028	2645	104.1339	170	105.6360
VOLKSWAGEN	Rabbit	3	1VWAB0172BV109315	2400	94.4882	161	100.0435
VOLVO	GL	3	YV1AX8849D1871561	2649	104.2913	180	111.8499
CHEVROLET	Cavalier	4	1G1AD69G9CC127028	2540	100.0000	169	105.0146
DODGE	600	4	1B3BE46C2DC185225	2616	102.9921	140	86.9943
FORD	Tempo	4	2FABP21R2EB119435	2537	99.8819	172	106.8788
FORD	Thunderbird	4	FABP4634DH120510	2642	104.0157	168	104.3932
HONDA	Prelude	4	JHMAB5226DC011100	2490	98.0315	151	93.8296
ISUZU	Impulse	4	JABAR07A8D0900856	2413	95.0000	174	108.1215
MAZDA-TOYO-KOGYO	626D	4	JM1GC2213D1506896	2667	105.0000	168	104.3932
MITSUBISHI	Tredia	4	JA3BF3646D2450934	2438	95.9843	161	100.0435
NISSAN	Pulsar	4	JN1MN23S1DM101674	2456	96.6929	150	93.2082
SUBARU	DL	4	JF1AM42B5DB444375	2456	96.6929	145	90.1013
TOYOTA	Camry	4	JT2SV12HXD0008687	2600	102.3622	180	111.8499
TOYOTA	Cressida	4	JT2MX62E0C0035028	2645	104.1339	170	105.6360
VOLVO	GL	4	YV1AX8849D1871561	2649	104.2913	180	111.8499

MANUFACTURER	MODEL	REP NO.	BRAKE CONF. YEAR	BRAKE TYPE FRONT	BRAKE TYPE REAR	BOOSTER TYPE	GVWR kg	GVWR lbs
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CHEVROLET	Cavalier	1	82	DISC	DRUM	VACUUM	--	--
CHEVROLET	Celebrity	1	82	DISC	DRUM	VACUUM	1684	3712.603
CHEVROLET	Citation #1	1	81	DISC	DRUM	--	1587	3498.754
CHEVROLET	Citation #2	1	81	DISC	DRUM	VAC INT	1575	3472.298
CHEVROLET	Citation #3	1	81	DISC	DRUM	VACUUM	1577	3476.708
CHRYSLER	Cordoba	1	80	DISC	DRUM	VAC INT	2198	4845.785
DODGE	Colt	1	82	DISC	DRUM	VAC INT	1400	3086.487
DODGE	Diplomat Wgn	1	82	DISC	DRUM	VACUUM	2275	5015.542
FORD	EXP	1	82	DISC	DRUM	VACUUM	1408	3104.124
FORD	Mustang	1	82	DISC	DRUM	VACUUM	1713	3776.538
HONDA	Civic	1	--	DISC	DRUM	VAC INT	1202	2649.970
MAZDA	RX-7	1	--	DISC	DRUM	VACUUM	1272	2804.294
MERCURY	Marquis Wgn	1	82	DISC	DRUM	VAC INT	2526	5568.905
NISSAN	Sentra	1	82	DISC	DRUM	VACUUM	1304	2874.842
OLDSMOBILE	Cruiser Wgn	1	82	DISC	DRUM	VACUUM	2526	5568.905
OLDSMOBILE	Toronado	1	82	DISC	DISC	HYDRAUL	2218	4889.878
PLYMOUTH	Gran Fury	1	82	DISC	DRUM	VACUUM	2216	4885.469
PLYMOUTH	Horizon	1	83	DISC	DRUM	VACUUM	1485	3273.881
RENAULT	18i	1	--	DISC	DRUM	VACUUM	1390	3064.441
TOYOTA	Cressida	1	82	DISC	DRUM	DIR VAC	1735	3825.040
TOYOTA	Starlet	1	81	DISC	DRUM	DIR VAC	1150	2535.329
VOLKSWAGEN	Rabbit	1	81	DISC	DRUM	VAC INT	1270	2799.885
VOLVO	244	1	82	DISC	DISC	VAC INT	1830	4034.480
CHEVROLET	Citation#1w/B	1	81	DISC	DRUM	VAC INT	1587	3498.754
FORD	Mustang w/B	1	82	DISC	DRUM	VACUUM	1713	3776.538
NISSAN	Sentra w/B	1	82	DISC	DRUM	VACUUM	1304	2874.842
OLDSMOBILE	Cruis Wgn w/B	1	82	DISC	DRUM	VACUUM	2526	5568.905
FORD	EXP/Escort	2	82	DISC	DRUM	VACUUM	1408	3104.124
FORD	Granada/LTD	2	--	DISC	DRUM	VACUUM	1950	4299.036
NISSAN	Sentra	2	82	DISC	DRUM	VACUUM	1304	2874.842
PLYMOUTH	Horizon	2	82	DISC	DRUM	VACUUM	1485	3273.881
BMW	735i	3	83	DISC	DISC	VACUUM	--	--
CHEVROLET	Caprice Clas	3	83	DISC	DRUM	VACUUM	2146	4731.144
CHEVROLET	Cavalier	3	83	DISC	DRUM	VACUUM	1520	3351.043
DODGE	600	3	--	DISC	DRUM	VACUUM	1749	3855.905
FORD	Granada	3	83	DISC	DRUM	VACUUM	1967	4336.515
FORD	Tempo	3	83	DISC	DRUM	VACUUM	1660	3659.692
FORD	Thunderbird	3	83	DISC	DRUM	VACUUM	1905	4199.828
HONDA	Prelude	3	83	DISC	DRUM	VACUUM	1465	3229.789
ISUZU	Impulse	3	83	DISC	DISC	VACUUM	1600	3527.414
MAZDA-TOYO-KOGYO	626D	3	83	DISC	DRUM	VACUUM	1603	3534.028
MITSUBISHI	Starion	3	83	DISC	DISC	VACUUM	1786	3937.476
MITSUBISHI	Tredia	3	83	DISC	DRUM	VACUUM	1474	3249.630
NISSAN	Pulsar	3	83	DISC	DRUM	VACUUM	1290	2843.978
PLYMOUTH	Horizon	3	83	DISC	DRUM	VACUUM	1485	3273.881
SUBARU	DL	3	83	DISC	DRUM	VACUUM	1547	3410.569
TOYOTA	Camry	3	83	DISC	DRUM	VACUUM	1625	3582.530
TOYOTA	Cressida	3	83	DISC	DRUM	DIR VAC	1735	3825.040
VOLKSWAGEN	Rabbit	3	83	DISC	DRUM	VAC INT	1270	2799.885
VOLVO	GL	3	83	DISC	DISC	VACUUM	1828	4030.071
CHEVROLET	Cavalier	4	83	DISC	DRUM	VACUUM	1520	3351.043
DODGE	600	4	--	DISC	DRUM	VACUUM	1749	3855.905
FORD	Tempo	4	83	DISC	DRUM	VACUUM	1660	3659.692
FORD	Thunderbird	4	83	DISC	DRUM	VACUUM	1905	4199.828
HONDA	Prelude	4	83	DISC	DRUM	VACUUM	1465	3229.789
ISUZU	Impulse	4	83	DISC	DISC	VACUUM	1600	3527.414
MAZDA-TOYO-KOGYO	626D	4	83	DISC	DRUM	VACUUM	1603	3534.028
MITSUBISHI	Tredia	4	83	DISC	DRUM	VACUUM	1474	3249.630
NISSAN	Pulsar	4	83	DISC	DRUM	VACUUM	1290	2843.978
SUBARU	DL	4	83	DISC	DRUM	VACUUM	1547	3410.569
TOYOTA	Camry	4	83	DISC	DRUM	VACUUM	1625	3582.530
TOYOTA	Cressida	4	83	DISC	DRUM	DIR VAC	1735	3825.040
VOLVO	GL	4	83	DISC	DISC	VACUUM	1828	4030.071

Table 1, Page 3 of 7

MANUFACTURER	MODEL	REP NO.	TOTAL TEST WEIGHT EMPTY kg	TOTAL TEST WEIGHT EMPTY lbs	TOTAL TEST WEIGHT LOADED kg	TOTAL TEST WEIGHT LOADED lbs	TOTAL TEST PAYLOAD lbs
CHEVROLET	Cavalier	1	1372	3024.758	1664	3668.511	643.753
CHEVROLET	Celebrity	1	1451	3198.924	1790	3946.295	747.371
CHEVROLET	Citation #1	1	1418	3126.171	1742	3840.472	714.301
CHEVROLET	Citation #2	1	--	--	1742	3840.472	--
CHEVROLET	Citation #3	1	--	--	1742	3840.472	--
CHRYSLER	Cordoba	1	1737	3829.449	2329	5134.592	1305.143
DODGE	Colt	1	930	2050.309	1308	2883.661	833.352
DODGE	Diplomat Wgn	1	1783	3930.862	2381	5249.233	1318.371
FORD	EXP	1	1166	2570.603	1381	3044.599	473.996
FORD	Mustang	1	1470	3240.812	1682	3708.194	467.382
HONDA	Civic	1	991	2184.792	1207	2660.993	476.201
MAZDA	RX-7	1	1219	2687.449	1275	2810.908	123.460
MERCURY	Marquis Wgn	1	1914	4219.669	2570	5665.909	1446.240
NISSAN	Sentra	1	1025	2259.749	1313	2894.684	634.935
OLDSMOBILE	Cruiser Wgn	1	2146	4731.144	2656	5855.508	1124.363
OLDSMOBILE	Toronado	1	2055	4530.523	2472	5449.855	919.332
PLYMOUTH	Gran Fury	1	1728	3809.607	2332	5141.206	1331.599
PLYMOUTH	Horizon	1	1220	2689.653	1551	3419.387	729.734
RENAULT	18i	1	1238	2729.337	1504	3315.769	586.433
TOYOTA	Cressida	1	1465	3229.789	1742	3840.472	610.684
TOYOTA	Starlet	1	964	2125.267	1156	2548.557	423.290
VOLKSWAGEN	Rabbit	1	1053	2321.479	1275	2810.908	489.429
VOLVO	244	1	1538	3390.727	1850	4078.573	687.846
CHEVROLET	Citation#1w/B	1	1418	3126.171	1742	3840.472	714.301
FORD	Mustang w/B	1	1470	3240.812	1682	3708.194	467.382
NISSAN	Sentra w/B	1	1025	2259.749	1313	2894.684	634.935
OLDSMOBILE	Cruis Wgn w/B	1	2146	4731.144	2656	5855.508	1124.363
FORD	EXP/Escort	2	1127	2484.622	1366	3011.530	526.908
FORD	Granada/LTD	2	1677	3697.171	1958	4316.673	619.502
NISSAN	Sentra	2	1025	2259.749	1313	2894.684	634.935
PLYMOUTH	Horizon	2	1221	2691.858	1551	3419.387	727.529
BMW	735i	3	1749	3855.905	2016	4444.542	588.637
CHEVROLET	Caprice Clas	3	1759	3877.951	2148	4735.554	857.603
CHEVROLET	Cavalier	3	1357	2991.688	1669	3679.534	687.846
DODGE	600	3	1329	2929.958	1746	3849.291	919.332
FORD	Granada	3	1620	3571.507	1987	4380.608	809.101
FORD	Tempo	3	1292	2848.387	1667	3675.125	826.738
FORD	Thunderbird	3	1589	3503.163	1868	4118.256	615.093
HONDA	Prelude	3	1159	2555.170	1409	3106.329	551.159
ISUZU	Impulse	3	1395	3075.464	1601	3529.619	454.155
MAZDA-TOYO-KOGYO	626D	3	1216	2680.835	1623	3578.121	897.286
MITSUBISHI	Starion	3	1540	3395.136	1796	3959.522	564.386
MITSUBISHI	Tredia	3	1168	2575.012	1481	3265.063	690.050
NISSAN	Pulsar	3	1050	2314.865	1291	2846.182	531.317
PLYMOUTH	Horizon	3	1220	2689.653	1551	3419.387	729.734
SUBARU	DL	3	1177	2594.854	1429	3150.422	555.568
TOYOTA	Camry	3	1310	2888.070	1629	3591.349	703.278
TOYOTA	Cressida	3	1465	3229.789	1742	3840.472	610.684
VOLKSWAGEN	Rabbit	3	1053	2321.479	1275	2810.908	489.429
VOLVO	GL	3	1504	3315.769	1849	4076.368	760.599
CHEVROLET	Cavalier	4	1357	2991.688	1669	3679.534	687.846
DODGE	600	4	1329	2929.958	1746	3849.291	919.332
FORD	Tempo	4	1292	2848.387	1667	3675.125	826.738
FORD	Thunderbird	4	1589	3503.163	1868	4118.256	615.093
HONDA	Prelude	4	1159	2555.170	1409	3106.329	551.159
ISUZU	Impulse	4	1395	3075.464	1601	3529.619	454.155
MAZDA-TOYO-KOGYO	626D	4	1216	2680.835	1623	3578.121	897.286
MITSUBISHI	Tredia	4	1168	2575.012	1481	3265.063	690.050
NISSAN	Pulsar	4	1050	2314.865	1291	2846.182	531.317
SUBARU	DL	4	1177	2594.854	1429	3150.422	555.568
TOYOTA	Camry	4	1310	2888.070	1629	3591.349	703.278
TOYOTA	Cressida	4	1465	3229.789	1742	3840.472	610.684
VOLVO	GL	4	1504	3315.769	1849	4076.368	760.599

Table 1, Page 4 of 7

MANUFACTURER	MODEL	REP NO.	GAWR FRONT kg	GAWR FRONT lbs	TOTAL TEST WT EMPTY FRONT kg	TOTAL TEST WT EMPTY FRONT lbs	TOTAL TEST WT LOADED FRONT kg	TOTAL TEST WT LOADED FRONT lbs
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CHEVROLET	Cavalier	1	--	--	898	1979.761	907	1999.603
CHEVROLET	Celebrity	1	884	1948.896	939	2070.151	962	2120.858
CHEVROLET	Citation #1	1	844	1860.711	903	1990.784	957	2109.834
CHEVROLET	Citation #2	1	844	1860.711	--	--	957	2109.834
CHEVROLET	Citation #3	1	840	1851.892	--	--	957	2109.834
CHRYSLER	Cordoba	1	1105	2436.120	980	2160.541	1202	2649.970
DODGE	Colt	1	728	1604.973	585	1289.710	662	1459.467
DODGE	Diplomat Wgn	1	1066	2350.139	930	2050.309	1138	2508.873
FORD	EXP	1	772	1701.977	717	1580.722	753	1660.089
FORD	Mustang	1	890	1962.124	835	1840.869	866	1909.213
HONDA	Civic	1	642	1415.375	594	1309.552	633	1395.533
MAZDA	RX-7	1	771	1699.772	627	1382.305	635	1399.942
MERCURY	Marquis Wgn	1	1194	2632.333	980	2160.541	1182	2605.877
NISSAN	Sentra	1	644	1419.784	599	1320.575	649	1430.807
OLDSMOBILE	Cruiser Wgn	1	1089	2400.846	1089	2400.846	1150	2535.329
OLDSMOBILE	Toronado	1	1211	2669.811	1277	2815.317	1315	2899.093
PLYMOUTH	Gran Fury	1	630	1388.919	975	2149.518	1148	2530.919
PLYMOUTH	Horizon	1	798	1759.298	780	1719.614	839	1849.688
RENAULT	18i	1	715	1576.313	771	1699.772	803	1770.321
TOYOTA	Cressida	1	950	2094.402	794	1750.479	862	1900.394
TOYOTA	Starlet	1	600	1322.780	510	1124.363	528	1164.046
VOLKSWAGEN	Rabbit	1	724	1596.155	640	1410.965	726	1600.564
VOLVO	244	1	855	1884.962	776	1710.796	857	1889.371
CHEVROLET	Citation#1w/B	1	844	1860.711	903	1990.784	957	2109.834
FORD	Mustang w/B	1	890	1962.124	835	1840.869	866	1909.213
NISSAN	Sentra w/B	1	644	1419.784	599	1320.575	649	1430.807
OLDSMOBILE	Cruis Wgn w/B	1	1089	2400.846	1089	2400.846	1150	2535.329
FORD	EXP/Escort	2	772	1701.977	712	1569.699	753	1660.089
FORD	Granada/LTD	2	981	2162.746	860	1895.985	971	2140.699
NISSAN	Sentra	2	644	1419.784	599	1320.575	649	1430.807
PLYMOUTH	Horizon	2	798	1759.298	780	1719.614	839	1849.688
BMW	735i	3	--	--	921	2030.468	952	2098.811
CHEVROLET	Caprice Clas	3	993	2189.201	943	2078.969	996	2195.815
CHEVROLET	Cavalier	3	858	1891.576	894	1970.942	909	2004.012
DODGE	600	3	941	2074.560	807	1779.139	934	2059.128
FORD	Granada	3	991	2184.792	828	1825.437	923	2034.877
FORD	Tempo	3	900	1984.170	807	1779.139	866	1909.213
FORD	Thunderbird	3	1047	2308.251	850	1873.939	952	2098.811
HONDA	Prelude	3	776	1710.796	701	1545.448	680	1499.151
ISUZU	Impulse	3	815	1796.776	778	1715.205	803	1770.321
MAZDA-TOYO-KOGYO	626D	3	889	1959.919	726	1600.564	891	1964.329
MITSUBISHI	Starion	3	861	1898.189	814	1794.572	871	1920.236
MITSUBISHI	Tredia	3	800	1763.707	701	1545.448	805	1774.730
NISSAN	Pulsar	3	700	1543.243	615	1355.849	658	1450.649
PLYMOUTH	Horizon	3	798	1759.298	780	1719.614	839	1849.688
SUBARU	DL	3	803	1770.321	678	1494.741	694	1530.016
TOYOTA	Camry	3	880	1940.078	782	1724.023	844	1860.711
TOYOTA	Cressida	3	950	2094.402	794	1750.479	862	1900.394
VOLKSWAGEN	Rabbit	3	724	1596.155	640	1410.965	726	1600.564
VOLVO	GL	3	855	1884.962	792	1746.070	853	1880.552
CHEVROLET	Cavalier	4	858	1891.576	894	1970.942	909	2004.012
DODGE	600	4	941	2074.560	807	1779.139	934	2059.128
FORD	Tempo	4	900	1984.170	807	1779.139	866	1909.213
FORD	Thunderbird	4	1047	2308.251	850	1873.939	952	2098.811
HONDA	Prelude	4	776	1710.796	701	1545.448	680	1499.151
ISUZU	Impulse	4	815	1796.776	778	1715.205	803	1770.321
MAZDA-TOYO-KOGYO	626D	4	889	1959.919	726	1600.564	891	1964.329
MITSUBISHI	Tredia	4	800	1763.707	701	1545.448	805	1774.730
NISSAN	Pulsar	4	700	1543.243	615	1355.849	658	1450.649
SUBARU	DL	4	803	1770.321	678	1494.741	694	1530.016
TOYOTA	Camry	4	880	1940.078	782	1724.023	844	1860.711
TOYOTA	Cressida	4	950	2094.402	794	1750.479	862	1900.394
VOLVO	GL	4	855	1884.962	792	1746.070	853	1880.552

Table 1, Page 5 of 7

MANUFACTURER	MODEL	REP NO.	GAWR REAR kg	GAWR REAR lbs	TOTAL TEST WT EMPTY REAR kg	TOTAL TEST WT EMPTY REAR lbs	TOTAL TEST WT LOADED REAR kg	TOTAL TEST WT LOADED REAR lbs
CHEVROLET	Cavalier	1	--	--	474	1044.997	757	1668.908
CHEVROLET	Celebrity	1	800	1763.707	512	1128.773	828	1825.437
CHEVROLET	Citation #1	1	744	1640.247	515	1135.387	785	1730.637
CHEVROLET	Citation #2	1	733	1615.996	--	--	785	1730.637
CHEVROLET	Citation #3	1	738	1627.019	--	--	785	1730.637
CHRYSLER	Cordoba	1	1116	2460.371	757	1668.908	1127	2484.622
DODGE	Colt	1	672	1481.514	345	760.599	646	1424.193
DODGE	Diplomat Wgn	1	1232	2716.109	853	1880.553	1243	2740.360
FORD	EXP	1	640	1410.965	449	989.881	630	1388.919
FORD	Mustang	1	832	1834.255	635	1399.943	816	1798.981
HONDA	Civic	1	580	1278.687	397	875.240	574	1265.459
MAZDA	RX-7	1	771	1699.772	592	1305.143	640	1410.965
MERCURY	Marquis Wgn	1	1400	3086.487	934	2059.128	1388	3060.032
NISSAN	Sentra	1	664	1463.877	426	939.174	664	1463.877
OLDSMOBILE	Cruiser Wgn	1	1438	3170.263	1057	2330.298	1506	3320.179
OLDSMOBILE	Toronado	1	1007	2220.066	778	1715.205	1157	2550.761
PLYMOUTH	Gran Fury	1	1154	2544.147	753	1660.090	1185	2612.491
PLYMOUTH	Horizon	1	710	1565.290	440	970.039	712	1569.699
RENAULT	18i	1	675	1488.128	467	1029.564	701	1545.448
TOYOTA	Cressida	1	971	2140.699	671	1479.310	880	1940.078
TOYOTA	Starlet	1	700	1543.243	454	1000.904	628	1384.510
VOLKSWAGEN	Rabbit	1	575	1267.664	413	910.514	549	1210.344
VOLVO	244	1	990	2182.587	762	1679.931	993	2189.201
CHEVROLET	Citation#1w/B	1	744	1640.247	515	1135.387	785	1730.637
FORD	Mustang w/B	1	832	1834.255	635	1399.943	816	1798.981
NISSAN	Sentra w/B	1	664	1463.877	426	939.174	664	1463.877
OLDSMOBILE	Cruis Wgn w/B	1	1438	3170.263	1506	3320.179	1506	3320.179
FORD	EXP/Escort	2	640	1410.965	415	914.923	613	1351.440
FORD	Granada/LTD	2	997	2198.020	817	1801.186	987	2175.973
NISSAN	Sentra	2	664	1463.877	426	939.174	664	1463.877
PLYMOUTH	Horizon	2	710	1565.290	440	970.039	712	1569.699
BMW	735i	3	--	--	828	1825.437	1064	2345.730
CHEVROLET	Caprice Clas	3	1153	2541.943	816	1798.981	1152	2539.738
CHEVROLET	Cavalier	3	562	1239.004	463	1020.746	760	1675.521
DODGE	600	3	830	1829.846	522	1150.819	812	1790.162
FORD	Granada	3	984	2169.359	792	1746.070	1064	2345.730
FORD	Tempo	3	810	1785.753	485	1069.248	801	1765.911
FORD	Thunderbird	3	925	2039.286	739	1629.225	916	2019.444
HONDA	Prelude	3	703	1549.857	458	1009.722	729	1607.178
ISUZU	Impulse	3	797	1757.093	617	1360.259	798	1759.298
MAZDA-TOYO-KOGYO	626D	3	730	1609.382	490	1080.271	732	1613.792
MITSUBISHI	Starion	3	925	2039.286	726	1600.564	925	2039.286
MITSUBISHI	Tredia	3	674	1485.923	467	1029.564	767	1690.954
NISSAN	Pulsar	3	640	1410.965	435	959.016	633	1395.533
PLYMOUTH	Horizon	3	710	1565.290	440	970.039	712	1569.699
SUBARU	DL	3	744	1640.247	499	1100.112	735	1620.406
TOYOTA	Camry	3	820	1807.799	528	1164.047	785	1730.637
TOYOTA	Cressida	3	971	2140.699	671	1479.310	880	1940.078
VOLKSWAGEN	Rabbit	3	575	1267.664	413	910.514	549	1210.344
VOLVO	GL	3	989	2180.383	712	1569.700	996	2195.815
CHEVROLET	Cavalier	4	562	1239.004	463	1020.746	760	1675.521
DODGE	600	4	830	1829.846	522	1150.819	812	1790.162
FORD	Tempo	4	810	1785.753	485	1069.248	801	1765.911
FORD	Thunderbird	4	925	2039.286	739	1629.225	916	2019.444
HONDA	Prelude	4	703	1549.857	458	1009.722	729	1607.178
ISUZU	Impulse	4	797	1757.093	617	1360.259	798	1759.298
MAZDA-TOYO-KOGYO	626D	4	730	1609.382	490	1080.271	732	1613.792
MITSUBISHI	Tredia	4	674	1485.923	467	1029.564	676	1490.332
NISSAN	Pulsar	4	640	1410.965	435	959.016	633	1395.533
SUBARU	DL	4	744	1640.247	499	1100.112	735	1620.406
TOYOTA	Camry	4	820	1807.799	528	1164.047	785	1730.637
TOYOTA	Cressida	4	971	2140.699	671	1479.310	880	1940.078
VOLVO	GL	4	989	2180.383	712	1569.700	996	2195.815

Table 1, Page 6 of 7

MANUFACTURER	MODEL	REP NO.	GAWR FRONT PLUS REAR lbs	GVWR MINUS GAWR SUM lbs	GAWR % REAR	TEST LADEN % REAR	DIFF % REAR GAWR MINUS TEST
CHEVROLET	Cavalier	1	--	--	--	45.49 %	--
CHEVROLET	Celebrity	1	3712.603	0.000	47.51 %	46.25 %	1.25 %
CHEVROLET	Citation #1	1	3500.959	-2.205	46.85 %	45.06 %	1.79 %
CHEVROLET	Citation #2	1	3476.708	-4.409	46.48 %	45.06 %	1.42 %
CHEVROLET	Citation #3	1	3478.912	-2.205	46.77 %	45.06 %	1.70 %
CHRYSLER	Cordoba	1	4896.492	-50.707	50.25 %	48.38 %	1.86 %
DODGE	Colt	1	3086.487	0.000	48.00 %	49.38 %	-1.39 %
DODGE	Diplomat Wgn	1	5066.249	-50.707	53.61 %	52.20 %	1.41 %
FORD	EXP	1	3112.943	-8.819	45.33 %	45.61 %	-0.29 %
FORD	Mustang	1	3796.379	-19.842	48.32 %	48.51 %	-0.20 %
HONDA	Civic	1	2694.062	-44.093	47.46 %	47.55 %	-0.09 %
MAZDA	RX-7	1	3399.545	-595.251	50.00 %	50.19 %	-0.20 %
MERCURY	Marquis Wgn	1	5718.820	-149.915	53.97 %	54.00 %	-0.04 %
NISSAN	Sentra	1	2883.661	-8.819	50.76 %	50.57 %	0.19 %
OLDSMOBILE	Cruiser Wgn	1	5571.110	-2.205	56.91 %	56.70 %	0.20 %
OLDSMOBILE	Toronado	1	4889.878	0.000	45.40 %	46.80 %	-1.40 %
PLYMOUTH	Gran Fury	1	3933.067	952.402	64.69 %	50.81 %	13.87 %
PLYMOUTH	Horizon	1	3324.588	-50.707	47.08 %	45.90 %	1.18 %
RENAULT	18i	1	3064.441	0.000	48.56 %	46.60 %	1.95 %
TOYOTA	Cressida	1	4235.102	-410.062	50.55 %	50.51 %	0.03 %
TOYOTA	Starlet	1	2866.024	-330.695	53.85 %	54.32 %	-0.48 %
VOLKSWAGEN	Rabbit	1	2863.819	-63.934	44.26 %	43.05 %	1.21 %
VOLVO	244	1	4067.549	-33.070	53.66 %	53.67 %	-0.02 %
CHEVROLET	Citation#1w/B	1	3500.959	-2.205	46.85 %	45.06 %	1.79 %
FORD	Mustang w/B	1	3796.379	-19.842	48.32 %	48.51 %	-0.20 %
NISSAN	Sentra w/B	1	2883.661	-8.819	50.76 %	50.57 %	0.19 %
OLDSMOBILE	Cruis Wgn w/B	1	5571.110	-2.205	56.91 %	56.70 %	0.20 %
FORD	EXP/Escort	2	3112.943	-8.819	45.33 %	44.87 %	0.45 %
FORD	Granada/LTD	2	4360.766	-61.730	50.40 %	50.40 %	0.00 %
NISSAN	Sentra	2	2883.661	-8.819	50.76 %	50.57 %	0.19 %
PLYMOUTH	Horizon	2	3324.588	-50.707	47.08 %	45.90 %	1.18 %
BMW	735i	3	--	--	--	52.77 %	--
CHEVROLET	Caprice Clas	3	4731.144	0.000	53.73 %	53.63 %	0.10 %
CHEVROLET	Cavalier	3	3130.580	220.463	39.58 %	45.53 %	-5.96 %
DODGE	600	3	3904.407	-48.502	46.87 %	46.50 %	0.36 %
FORD	Granada	3	4354.152	-17.637	49.82 %	53.54 %	-3.73 %
FORD	Tempo	3	3769.924	-110.232	47.37 %	48.05 %	-0.68 %
FORD	Thunderbird	3	4347.538	-147.710	46.91 %	49.03 %	-2.13 %
HONDA	Prelude	3	3260.653	-30.865	47.53 %	51.73 %	-4.21 %
ISUZU	Impulse	3	3553.870	-26.456	49.44 %	49.84 %	-0.40 %
MAZDA-TOYO-KOGYO	626D	3	3569.302	-35.274	45.09 %	45.10 %	-0.01 %
MITSUBISHI	Starion	3	3937.476	0.000	51.79 %	51.50 %	0.29 %
MITSUBISHI	Tredia	3	3249.630	0.000	45.73 %	51.78 %	-6.06 %
NISSAN	Pulsar	3	2954.209	-110.232	47.76 %	49.03 %	-1.27 %
PLYMOUTH	Horizon	3	3324.588	-50.707	47.08 %	45.90 %	1.18 %
SUBARU	DL	3	3410.569	0.000	48.09 %	51.43 %	-3.34 %
TOYOTA	Camry	3	3747.878	-165.348	48.24 %	48.18 %	0.05 %
TOYOTA	Cressida	3	4235.102	-410.062	50.55 %	50.51 %	0.03 %
VOLKSWAGEN	Rabbit	3	2863.819	-63.934	44.26 %	43.05 %	1.21 %
VOLVO	GL	3	4065.345	-35.274	53.63 %	53.86 %	-0.23 %
CHEVROLET	Cavalier	4	3130.580	220.463	39.58 %	45.53 %	-5.96 %
DODGE	600	4	3904.407	-48.502	46.87 %	46.50 %	0.36 %
FORD	Tempo	4	3769.924	-110.232	47.37 %	48.05 %	-0.68 %
FORD	Thunderbird	4	4347.538	-147.710	46.91 %	49.03 %	-2.13 %
HONDA	Prelude	4	3260.653	-30.865	47.53 %	51.73 %	-4.21 %
ISUZU	Impulse	4	3553.870	-26.456	49.44 %	49.84 %	-0.40 %
MAZDA-TOYO-KOGYO	626D	4	3569.302	-35.274	45.09 %	45.10 %	-0.01 %
MITSUBISHI	Tredia	4	3249.630	0.000	45.73 %	45.64 %	0.08 %
NISSAN	Pulsar	4	2954.209	-110.232	47.76 %	49.03 %	-1.27 %
SUBARU	DL	4	3410.569	0.000	48.09 %	51.43 %	-3.34 %
TOYOTA	Camry	4	3747.878	-165.348	48.24 %	48.18 %	0.05 %
TOYOTA	Cressida	4	4235.102	-410.062	50.55 %	50.51 %	0.03 %
VOLVO	GL	4	4065.345	-35.274	53.63 %	53.86 %	-0.23 %

Table 1, Page 7 of 7

MANUFACTURER	MODEL	REP NO.	WORST CASE % REAR GAWR/GVWR	DIFF. OF % REAR GAWR/GVWR MINUS TEST
CHEVROLET	Cavalier	1	--	--
CHEVROLET	Celebrity	1	47.51 %	1.25 %
CHEVROLET	Citation #1	1	46.88 %	1.82 %
CHEVROLET	Citation #2	1	46.54 %	1.48 %
CHEVROLET	Citation #3	1	46.80 %	1.73 %
CHRYSLER	Cordoba	1	50.77 %	2.38 %
DODGE	Colt	1	48.00 %	-1.39 %
DODGE	Diplomat Wgn	1	54.15 %	1.95 %
FORD	EXP	1	45.45 %	-0.16 %
FORD	Mustang	1	48.57 %	0.06 %
HONDA	Civic	1	48.25 %	0.70 %
MAZDA	RX-7	1	60.61 %	10.42 %
MERCURY	Marquis Wgn	1	55.42 %	1.42 %
NISSAN	Sentra	1	50.92 %	0.35 %
OLDSMOBILE	Cruiser Wgn	1	56.93 %	0.23 %
OLDSMOBILE	Toronado	1	45.40 %	-1.40 %
PLYMOUTH	Gran Fury	1	52.08 %	1.26 %
PLYMOUTH	Horizon	1	47.81 %	1.91 %
RENAULT	18i	1	48.56 %	1.95 %
TOYOTA	Cressida	1	55.97 %	5.45 %
TOYOTA	Starlet	1	60.87 %	6.54 %
VOLKSWAGEN	Rabbit	1	45.28 %	2.22 %
VOLVO	244	1	54.10 %	0.42 %
CHEVROLET	Citation#1w/B	1	46.88 %	1.82 %
FORD	Mustang w/B	1	48.57 %	0.06 %
NISSAN	Sentra w/B	1	50.92 %	0.35 %
OLDSMOBILE	Cruis Wgn w/B	1	56.93 %	0.23 %
FORD	EXP/Escort	2	45.45 %	0.58 %
FORD	Granada/LTD	2	51.13 %	0.72 %
NISSAN	Sentra	2	50.92 %	0.35 %
PLYMOUTH	Horizon	2	47.81 %	1.91 %
BMW	735i	3	--	--
CHEVROLET	Caprice Clas	3	53.73 %	0.10 %
CHEVROLET	Cavalier	3	36.97 %	-8.56 %
DODGE	600	3	47.46 %	0.95 %
FORD	Granada	3	50.03 %	-3.52 %
FORD	Tempo	3	48.80 %	0.74 %
FORD	Thunderbird	3	48.56 %	-0.48 %
HONDA	Prelude	3	47.99 %	-3.75 %
ISUZU	Impulse	3	49.81 %	-0.03 %
MAZDA-TOYO-KOGYO	626D	3	45.54 %	0.44 %
MITSUBISHI	Starion	3	51.79 %	0.29 %
MITSUBISHI	Tredia	3	45.73 %	-6.06 %
NISSAN	Pulsar	3	49.61 %	0.58 %
PLYMOUTH	Horizon	3	47.81 %	1.91 %
SUBARU	DL	3	48.09 %	-3.34 %
TOYOTA	Camry	3	50.46 %	2.27 %
TOYOTA	Cressida	3	55.97 %	5.45 %
VOLKSWAGEN	Rabbit	3	45.28 %	2.22 %
VOLVO	GL	3	54.10 %	0.24 %
CHEVROLET	Cavalier	4	36.97 %	-8.56 %
DODGE	600	4	47.46 %	0.95 %
FORD	Tempo	4	48.80 %	0.74 %
FORD	Thunderbird	4	48.56 %	-0.48 %
HONDA	Prelude	4	47.99 %	-3.75 %
ISUZU	Impulse	4	49.81 %	-0.03 %
MAZDA-TOYO-KOGYO	626D	4	45.54 %	0.44 %
MITSUBISHI	Tredia	4	45.73 %	0.08 %
NISSAN	Pulsar	4	49.61 %	0.58 %
SUBARU	DL	4	48.09 %	-3.34 %
TOYOTA	Camry	4	50.46 %	2.27 %
TOYOTA	Cressida	4	55.97 %	5.45 %
VOLVO	GL	4	54.10 %	0.24 %

TEST CONDITIONS

	Version #1 Harmonized Procedure	Version #2 Harmonized Procedure	Version #3 Harmonized Procedure	Modified Harmonized Procedure	Proposed FMVSS 135 Procedure
Test Weight Laden	GVWR	GVWR	GVWR	GVWR	GVWR
Test Weight Laden	Unloaded + *300 lbs.*	Unloaded + 396 lbs.	Unloaded + 396 lbs.	Unloaded + 396 lbs.	Unloaded + 396 lbs.
Initial Temperature	*149°F to 212°F*	*149°F to 212°F*	122°F to 212°F	122°F to 212°F	122°F to 212°F
Effectiveness Test Speed, mph N = Neutral G = Gear	62.1mph N 80% Vmax G	62.1mph N 80% Vmax G	62.1mph N 80% Vmax G	62.1mph N 80% Vmax G	62.1mph N 80% V_{max} G
Number of Attempts	4	4	4	4	4
Pedal Force, Lbs.	14.6 to 112.4	14.6 to 112.4	14.6 to 112.4	14.6 to 112.4	14.6 to 112.4
Wheel Skid	None	None	None	None	None
Brake Adjustment	Mfg. Specs.	Mfg. Specs.	Mfg. Specs.	Mfg. Specs.	Mfg. Specs.
Automatic Adjusters	*Not Mentioned*	*Optional, but if Fitted Operative*	*Optional but if Fitted Operative*	*Optional but if Fitted Operative*	Required and Operative
Test Road	*"Portland Cement or Similar Surfaces"*	*"Portland Cement or Similar Surfaces"*	*"Surface Affording Good Adhesion"*	*"Surface Affording Good Adhesion"*	Skid No. 81
Stability	11.5 ft. Lane < ± 15° Yaw	11.5 ft. Lane < ± 15° Yaw	11.5 ft. Lane < ± 15° Yaw	11.5 ft. Lane < ± 15° Yaw	11.5 ft. Lane < ± 15° Yaw

TABLE 2
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BURNISH

	Version #1 Harmonized Procedure	Version #2 Harmonized Procedure	Version #3 Harmonized Procedure	Modified Harmonized Procedure	Proposed FMVSS 135 Procedure
Preburnish Inst. check	*None*	*None*	*None*	*None*	**10 Stops from 31.1 mph @ < 9.8 ft/s²**
Preburnish Effectiveness	*None*	*None*	*None*	**62.1 mph** *to Establish a Database*	**62.1 mph 236 feet**
Burnish	*None*	*50 Stops 49.7 mph 9.8 ft/s² 1.24 miles or <212°F between*	*50 Stops 49.7 mph 9.8 ft/s² 1.24 miles or <212°F between*	*46 Stops 49.7 mph 9.8 ft/s² 1.24 miles or <212°F between*	**36 Stops 49.7 mph 9.8 ft/s² 1.24 miles or <212°F between**
Reburnish	*None*	**(Optional) Additional 50 Stops with Additional Effect. Test**	**(Optional) Additional 50 Stops with Additional Effect. Test**	**(Optional) Additional 50 Stops with Additional Effect. Test**	**(Optional) Additional 50 Stops with Additional Effect. Test**

FULL SYSTEM EFFECTIVENESS

	Version #1 Harmonized Procedure*	Version #2 Harmonized Procedure	Version #3 Harmonized Procedure	Modified Harmonized Procedure	Proposed FMVSS 135 Procedure
Laden	62.1 mph Neutral *252.6 ft* *19 ft/s²*	62.1 mph Neutral *252.6 ft* *19 ft/s2*	62.1 mph Neutral *252.6 ft* *19 ft/s2*	62.1 mph Neutral *252.6 ft* *19 ft/s2*	62.1 mph Neutral 214 ft 21 ft/s²
	80% Vmax In Gear *13.1 ft/s2*	80% Vmax In Gear *16.4 ft/s2*	80% Vmax In Gear *16.4 ft/s2*	80% Vmax In Gear *16.4 ft/s2*	80% V_{max} In Gear 19 ft/s²
Engine Off System Charged	*1 Stop* 62.1 mph Neutral *252.6 ft*	62.1 mph Neutral *252.6 ft*	62.1 mph Neutral *252.6 ft*	62.1 mph Neutral *252.6 ft*	62.1 mph Neutral 236 ft
Unladen	62.1 mph Neutral *252.6 ft* *19 ft/s2*	62.1 mph Neutral *252.6 ft* *19 ft/s2*	62.1 mph Neutral *252.6 ft* *19 ft/s2*	62.1 mph Neutral *252.6 ft* *19 ft/s2*	62.1 mph Neutral 214 ft 21 ft/s²
	80% Vmax In Gear *13.1 ft/s2*	80% Vmax In Gear *16.4 ft/s2*	80% Vmax In Gear *16.4 ft/s2*	80% Vmax In Gear *16.4 ft/s2*	80% V_{max} In Gear 19 ft/s²

TABLE 2
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*This Version Ran Fade & Recovery Between Engine Off and Unladen Tests.

SECONDARY EFFECTIVENESS (Partial System)

	Version #1 Harmonized Procedure	Version #2 Harmonized Procedure	Version #3 Harmonized Procedure	Modified Harmonized Procedure	Proposed FMVSS 135 Procedure
Partial System (Each Circuit)	62.1 mph *689 ft* Laden & Unladen *and 80% V_{max} Stability Check*	62.1 mph *580.7 ft* Laden & Unladen	62.1 mph *580.7 ft* Laden & Unladen	62.1 mph *580.7 ft* Laden & Unladen	62.1 mph 590 ft Laden & Unladen
Power Assist Failure Depleted	62.1 mph *689 ft* Laden *and 80% V_{max} Stability Check*	62.1 mph *580.7 ft* Laden	62.1 mph *580.7 ft* Laden	62.1 mph *580.7 ft* Laden	62.1 mph 590 ft Laden
Failed Anti-lock	62.1 mph *689 ft* Laden & Unladen *and 80% Vmax Stability Check*	62.1 mph *580.7 ft* Laden & Unladen	62.1 mph *580.7 ft* Laden & Unladen	62.1 mph *580.7 ft* Laden & Unladen	62.1 mph 263 ft Laden & Unladen
Failed Variable Prop. Valve	62.1 mph *689 ft* Laden & Unladen *and 80% Vmax Stability Check*	62.1 mph *580.7 ft* Laden & Unladen	62.1 mph *580.7 ft* Laden & Unladen	62.1 mph *580.7 ft* Laden & Unladen	62.1 mph 263 ft Laden & Unladen

FADE & RECOVERY

	Version #1 Harmonized Procedure*	Version #2 Harmonized Procedure	Version #3 Harmonized Procedure	Modified Harmonized Procedure	Proposed FMVSS 135 Procedure
Baseline Check	*3 Stops* *50 mph* *@ 9.8 ft/s²*	None	*2 Snubs* *80% Vmax to* *1/2 Intial Speed* *@ 9.8 ft/s2*	*2 Snubs* *80% Vmax to* *1/2 Intial Speed* *@ 9.8 ft/s2*	None
Heating Cycle	15 Snubs 80% Vmax to 1/2 Intial Speed *@ Pedal Force* *from Baseline* *45 sec / interval*	15 Snubs 80% Vmax to 1/2 Intial Speed *@ Pedal Force* *from 1st Snub* *@ 9.8 ft/s2* *45 sec / interval*	15 Snubs 80% Vmax to 1/2 Intial Speed *@ Pedal Force* *from Baseline* *45 sec / interval*	15 Snubs 80% Vmax to 1/2 Intial Speed *@ Pedal Force* *from Baseline* 30 sec / interval or 80 Snubs 34.2 to 15.6 mph 15 sec / interval	15 Snubs 80% Vmax to 1/2 Intial Speed @ 9.8 ft/s² 30 sec / interval or 80 Snubs 34.2 to 15.6 mph 15 sec / interval
Hot Stop	1 Stop 62.1 mph @ Pedal Force from Effect.	1 Stop 62.1 mph @ Pedal Force from Effect.	1 Stop 62.1 mph @ Pedal Force from Effect.	1 Stop 62.1 mph @ Pedal Force from Effect.	1 Stop 62.1 mph @ Pedal Force from Effect.
Recovery or Cooling	*5 Stops* *31.1 mph* @ 9.8 ft/s2 .93 miles between stops	4 Stops 31.1 mph *@ Pedal Force* *from Baseline* .93 miles between stops	4 Stops 31.1 mph *@ Pedal Force* *from Baseline* .93 miles between stops	4 Stops 31.1 mph *@ Pedal Force* *from Baseline* .93 miles between stops	4 Stops 31.1 mph @ 9.8 ft/s² .93 miles between stops
Post Fade Effectiveness	1 Stop 62.1 mph @ Pedal Force from Effect. *60% Decel.* *from Effect.*	1 Stop 62.1 mph @ Pedal Force from Effect. *70% Stopping* *Distance* *from Effect.*	1 Stop 62.1 mph @ Pedal Force from Effect. *70% Stopping* *Distance* *from Effect.*	1 Stop 62.1 mph @ Pedal Force from Effect. *60% Decel.* *from Effect.*	1 Stop 62.1 mph @ Pedal Force from Effect. 70% to 120% Stopping Dist. from Effect.

*This Version Ran Fade & Recovery Between Full System Engine Off Test and Full System Unladen Test.

PARKING BRAKE

	Version #1 Harmonized Procedure*	Version #2 Harmonized Procedure	Version #3 Harmonized Procedure	Modified Harmonized Procedure	Proposed FMVSS 135 Procedure
Apply force, Lbs.					
Foot Actuation	112.4	112.4	112.4	112.4	112.4
Hand Actuation	*89.9*	*89.9*	*89.9*	*89.9*	71.9
Grade Holding	20%	20%	20%	20%	20%
Parking Pawl	Not Allowed	Not Allowed	Not Allowed	Not Allowed	Not Allowed
Dynamic Test	*49.7 mph* *4.92 ft/s2* *or* 37.3 mph 6.56 ft/s2	*49.7 mph* *4.92 ft/s2* *or* 37.3 mph 6.56 ft/s2	*49.7 mph* *4.92 ft/s2* *or* 37.3 mph 6.56 ft/s2	*49.7 mph* *4.92 ft/s2* *or* 37.3 mph 6.56 ft/s2	37.3 mph 238 ft (6.56 ft/s^2) Final Decel. 4.92 ft/s^2
Trailer Test	*12 % Grade with max. Allowable Trailer*	*12 % Grade with max. Allowable Trailer*	*12 % Grade with max. Allowable Trailer*	*12 % Grade with max. Allowable Trailer*	None

*This Version Ran the Dynamic Test Before the Gradient Holding.

TABLE 2

MISC. TESTS

	Version #1 Harmonized Procedure	Version #2 Harmonized Procedure	Version #3 Harmonized Procedure	Modified Harmonized Procedure	Proposed FMVSS 135 Procedure
Water Recovery	*Similar to FMVSS 105*	None	None	None	None
Spike Stops	*None*	*None*	*None*	*None*	10 Stops 31.1 mph Neutral @ 202.3 Lbs. Pedal Force
Final Effectiveness	*None*	*None*	*None*	62.1 mph *to Establish a Database*	62.1 mph 236 ft

BRAKE BALANCE

	Version #1 Harmonized Procedure	Version #2 Harmonized Procedure	Version #3 Harmonized Procedure	Modified Harmonized Procedure	Proposed FMVSS 135 Procedure
Brake Balance	"Adhesion Utilization" Concept *Like Annex 10 R.13*	*Single Axle Procedure After Rebuilding and Burnishing the Brakes*	*Undecided in this Version,* *But,* *NHTSA Ran a* Vehicle Test (Radlinski Proc.) Based on Front Only and Rear Only Stops	"Adhesion Utilization" Concept *Like Annex 10 R.13 Expected* *But,* *Details of Regulation not yet Worked Out*	"Adhesion Utilization" Concept but Differs from Annex 10 R.13 Vehicle Test (Radlinski Proc.) Based on Front Only and Rear Only Stops No Exception in Lock Sequence Requirement is in Gear

TABLE 2
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MANUFACTURER	MODEL	REP NO.	NHTSA ADH. UTIL. CURVE	GM BRAKE BALA. CALC.	BURN PROC	GVWR PRE-BURN EFF. m	%PASS -FAIL	MAX. PEDAL FORCE N
CHEVROLET	Cavalier	1	--	FAIL	--	68	5.6 %	254
CHEVROLET	Celebrity	1	FAIL	FAIL	--	68	5.6 %	480
CHEVROLET	Citation #1	1	--	FAIL	--	68	5.6 %	249
CHEVROLET	Citation #2	1	--	FAIL	--	69	4.2 %	276
CHEVROLET	Citation #3	1	--	FAIL	--	65	9.7 %	454
CHRYSLER	Cordoba	1	FAIL	FAIL	--	57	20.8 %	271
DODGE	Colt	1	--	PASS	--	67	6.9 %	494
DODGE	Diplomat Wgn	1	--	FAIL	--	62	13.9 %	302
FORD	EXP	1	PASS	FAIL	--	70	2.8 %	258
FORD	Mustang	1	PASS	FAIL	--	58	19.4 %	302
HONDA	Civic	1	PASS	FAIL	--	58	19.4 %	485
MAZDA	RX-7	1	--	PASS	--	58	19.4 %	249
MERCURY	Marquis Wgn	1	PASS	FAIL	--	68	5.6 %	231
NISSAN	Sentra	1	PASS	FAIL	--	68	5.6 %	231
OLDSMOBILE	Cruiser Wgn	1	--	FAIL	--	68	5.6 %	231
OLDSMOBILE	Toronado	1	--	FAIL	--	64	11.1 %	338
PLYMOUTH	Gran Fury	1	--	FAIL	--	67	6.9 %	258
PLYMOUTH	Horizon	1	--	FAIL	--	61	15.3 %	302
RENAULT	18i	1	FAIL	FAIL	--	63	12.5 %	480
TOYOTA	Cressida	1	--	FAIL	--	53	26.4 %	507
TOYOTA	Starlet	1	--	FAIL	--	58	19.4 %	454
VOLKSWAGEN	Rabbit	1	--	FAIL	--	66	8.3 %	382
VOLVO	244	1	--	FAIL	--	60	16.7 %	489
CHEVROLET	Citation#1w/B	1	--	FAIL	105	--	--	--
FORD	Mustang w/B	1	--	FAIL	105	--	--	--
NISSAN	Sentra w/B	1	--	FAIL	105	--	--	--
OLDSMOBILE	Cruis Wgn w/B	1	--	FAIL	105	--	--	--
FORD	EXP/Escort	2	PASS	FAIL	REF1	--	--	--
FORD	Granada/LTD	2	PASS	FAIL	REF1	--	--	--
NISSAN	Sentra	2	PASS	PASS	REF1	--	--	--
PLYMOUTH	Horizon	2	PASS	PASS	REF1	--	--	--
BMW	735i	3	PASS	PASS	REF1	--	--	--
CHEVROLET	Caprice Clas	3	FAIL	FAIL	REF1	--	--	--
CHEVROLET	Cavalier	3	PASS	FAIL	REF1	--	--	--
DODGE	600	3	PASS	FAIL	REF1	--	--	--
FORD	Granada	3	FAIL	FAIL	REF1	--	--	--
FORD	Tempo	3	FAIL	FAIL	REF1	--	--	--
FORD	Thunderbird	3	PASS	FAIL	REF1	--	--	--
HONDA	Prelude	3	FAIL	FAIL	REF1	--	--	--
ISUZU	Impulse	3	FAIL	FAIL	REF1	--	--	--
MAZDA-TOYO-KOGYO	626D	3	PASS	PASS	REF1	--	--	--
MITSUBISHI	Starion	3	PASS	PASS	REF1	--	--	--
MITSUBISHI	Tredia	3	FAIL	FAIL	REF1	--	--	--
NISSAN	Pulsar	3	PASS	PASS	REF1	--	--	--
PLYMOUTH	Horizon	3	PASS	FAIL	REF1	--	--	--
SUBARU	DL	3	FAIL	FAIL	REF1	--	--	--
TOYOTA	Camry	3	PASS	PASS	REF1	--	--	--
TOYOTA	Cressida	3	FAIL	FAIL	REF1	--	--	--
VOLKSWAGEN	Rabbit	3	PASS	PASS	REF1	--	--	--
VOLVO	GL	3	PASS	FAIL	REF1	--	--	--
CHEVROLET	Cavalier	4	--	FAIL	REF1	63	12.5 %	374
DODGE	600	4	--		REF1	55	23.6 %	271
FORD	Tempo	4	--	FAIL	REF1	66	8.3 %	267
FORD	Thunderbird	4	--	--	--	--	--	--
HONDA	Prelude	4	--	FAIL	REF1	64	11.1 %	289
ISUZU	Impulse	4	--	FAIL	REF1	59	18.1 %	516
MAZDA-TOYO-KOGYO	626D	4	--	PASS	REF1	57	20.8 %	494
MITSUBISHI	Tredia	4	--	PASS	REF1	69	4.2 %	512
NISSAN	Pulsar	4	--	PASS	REF1	55	23.6 %	405
SUBARU	DL	4	--	PASS	REF1	55	23.6 %	498
TOYOTA	Camry	4	--	PASS	REF1	53	26.4 %	485
TOYOTA	Cressida	4	--	PASS	REF1	60	16.7 %	480
VOLVO	GL	4	--	PASS	REF1	62	13.9 %	338

MANUFACTURER	MODEL	REP NO.	1ST GVWR COLD EFF. m	%PASS -FAIL	MAX. PEDAL FORCE N	2ND GVWR COLD EFF. m	%PASS -FAIL	MAX. PEDAL FORCE N
CHEVROLET	Cavalier	1	--	--	--	--	--	--
CHEVROLET	Celebrity	1	--	--	--	--	--	--
CHEVROLET	Citation #1	1	--	--	--	--	--	--
CHEVROLET	Citation #2	1	--	--	--	--	--	--
CHEVROLET	Citation #3	1	--	--	--	--	--	--
CHRYSLER	Cordoba	1	--	--	--	--	--	--
DODGE	Colt	1	--	--	--	--	--	--
DODGE	Diplomat Wgn	1	--	--	--	--	--	--
FORD	EXP	1	--	--	--	--	--	--
FORD	Mustang	1	--	--	--	--	--	--
HONDA	Civic	1	--	--	--	--	--	--
MAZDA	RX-7	1	--	--	--	--	--	--
MERCURY	Marquis Wgn	1	--	--	--	--	--	--
NISSAN	Sentra	1	--	--	--	--	--	--
OLDSMOBILE	Cruiser Wgn	1	--	--	--	--	--	--
OLDSMOBILE	Toronado	1	--	--	--	--	--	--
PLYMOUTH	Gran Fury	1	--	--	--	--	--	--
PLYMOUTH	Horizon	1	--	--	--	--	--	--
RENAULT	18i	1	--	--	--	--	--	--
TOYOTA	Cressida	1	--	--	--	--	--	--
TOYOTA	Starlet	1	--	--	--	--	--	--
VOLKSWAGEN	Rabbit	1	--	--	--	--	--	--
VOLVO	244	1	--	--	--	--	--	--
CHEVROLET	Citation#1w/B	1	65	0.0 %	462	--	--	--
FORD	Mustang w/B	1	57	12.3 %	374	--	--	--
NISSAN	Sentra w/B	1	63	3.1 %	320	--	--	--
OLDSMOBILE	Cruis Wgn w/B	1	62	4.6 %	258	--	--	--
FORD	EXP/Escort	2	62	4.6 %	494	63	3.1 %	516
FORD	Granada/LTD	2	61	6.2 %	267	59	9.2 %	382
NISSAN	Sentra	2	64	1.5 %	471	59	9.2 %	480
PLYMOUTH	Horizon	2	53	18.5 %	289	52	20.0 %	267
BMW	735i	3	46	29.2 %	552	45	30.8 %	552
CHEVROLET	Caprice Clas	3	68	-4.6 %	240	66	-1.5 %	182
CHEVROLET	Cavalier	3	65	0.0 %	231	68	-4.6 %	227
DODGE	600	3	58	10.8 %	227	58	10.8 %	249
FORD	Granada	3	61	6.2 %	538	59	9.2 %	485
FORD	Tempo	3	62	4.6 %	454	58	10.8 %	489
FORD	Thunderbird	3	59	9.2 %	356	58	10.8 %	445
HONDA	Prelude	3	64	1.5 %	445	60	7.7 %	462
ISUZU	Impulse	3	58	10.8 %	387	55	15.4 %	342
MAZDA-TOYO-KOGYO	626D	3	61	6.2 %	356	61	6.2 %	534
MITSUBISHI	Starion	3	65	0.0 %	498	57	12.3 %	498
MITSUBISHI	Tredia	3	60	7.7 %	516	60	7.7 %	462
NISSAN	Pulsar	3	57	12.3 %	498	58	10.8 %	498
PLYMOUTH	Horizon	3	62	4.6 %	391	62	4.6 %	382
SUBARU	DL	3	51	21.5 %	534	52	20.0 %	512
TOYOTA	Camry	3	55	15.4 %	498	56	13.8 %	507
TOYOTA	Cressida	3	54	16.9 %	516	55	15.4 %	489
VOLKSWAGEN	Rabbit	3	59	9.2 %	560	59	9.2 %	649
VOLVO	GL	3	68	-4.6 %	222	68	-4.6 %	182
CHEVROLET	Cavalier	4	64	1.5 %	391	64	1.5 %	307
DODGE	600	4	64	1.5 %	178	61	6.2 %	209
FORD	Tempo	4	62	4.6 %	400	64	1.5 %	302
FORD	Thunderbird	4	--	--	--	--	--	--
HONDA	Prelude	4	63	3.1 %	276	61	6.2 %	431
ISUZU	Impulse	4	59	9.2 %	489	58	10.8 %	516
MAZDA-TOYO-KOGYO	626D	4	64	1.5 %	369	63	3.1 %	480
MITSUBISHI	Tredia	4	64	1.5 %	409	66	-1.5 %	414
NISSAN	Pulsar	4	56	13.8 %	356	56	13.8 %	356
SUBARU	DL	4	57	12.3 %	471	56	13.8 %	498
TOYOTA	Camry	4	60	7.7 %	480	60	7.7 %	356
TOYOTA	Cressida	4	63	3.1 %	489	60	7.7 %	445
VOLVO	GL	4	60	7.7 %	329	61	6.2 %	285

Table 3, Page 3 of 8

MANUFACTURER	MODEL	REP NO.	GVWR HIGH SPEED EFF. m	%PASS -FAIL	MAX. PEDAL FORCE N	LLVW COLD EFF. m	%PASS -FAIL	MAX. PEDAL FORCE N
CHEVROLET	Cavalier	1	117	9.5 %	387	57	12.3 %	218
CHEVROLET	Celebrity	1	125	3.3 %	409	60	7.7 %	178
CHEVROLET	Citation #1	1	116	8.1 %	285	65	0.0 %	267
CHEVROLET	Citation #2	1	114	9.7 %	391	56	13.8 %	365
CHEVROLET	Citation #3	1	117	7.3 %	374	58	10.8 %	391
CHRYSLER	Cordoba	1	81	21.0 %	285	55	15.4 %	267
DODGE	Colt	1	99	3.4 %	485	51	21.5 %	427
DODGE	Diplomat Wgn	1	86	18.2 %	320	61	6.2 %	258
FORD	EXP	1	106	10.9 %	409	58	10.8 %	503
FORD	Mustang	1	98	16.7 %	360	59	9.2 %	240
HONDA	Civic	1	68	20.9 %	489	56	13.8 %	365
MAZDA	RX-7	1	131	21.8 %	294	51	21.5 %	222
MERCURY	Marquis Wgn	1	98	8.0 %	302	61	6.2 %	347
NISSAN	Sentra	1	87	9.3 %	258	60	7.7 %	160
OLDSMOBILE	Cruiser Wgn	1	111	14.1 %	329	58	10.8 %	258
OLDSMOBILE	Toronado	1	78	19.8 %	311	60	7.7 %	178
PLYMOUTH	Gran Fury	1	84	13.6 %	302	56	13.8 %	285
PLYMOUTH	Horizon	1	132	-34.0 %	409	58	10.8 %	187
RENAULT	18i	1	79	18.8 %	302	58	10.8 %	374
TOYOTA	Cressida	1	110	15.9 %	498	57	12.3 %	231
TOYOTA	Starlet	1	79	22.9 %	605	57	12.3 %	427
VOLKSWAGEN	Rabbit	1	102	13.3 %	329	55	15.4 %	222
VOLVO	244	1	122	16.5 %	552	52	20.0 %	187
CHEVROLET	Citation#1w/B	1	119	5.8 %	454	57	12.3 %	356
FORD	Mustang w/B	1	96	18.4 %	498	61	6.2 %	329
NISSAN	Sentra w/B	1	83	13.5 %	356	56	13.8 %	214
OLDSMOBILE	Cruis Wgn w/B	1	125	3.3 %	231	55	15.4 %	356
FORD	EXP/Escort	2	118	0.9 %	498	64	1.5 %	498
FORD	Granada/LTD	2	83	16.9 %	440	62	4.6 %	311
NISSAN	Sentra	2	82	14.5 %	391	52	20.0 %	396
PLYMOUTH	Horizon	2	114	19.4 %	276	50	23.1 %	196
BMW	735i	3	125	36.1 %	534	44	32.3 %	445
CHEVROLET	Caprice Clas	3	116	2.5 %	294	61	6.2 %	182
CHEVROLET	Cavalier	3	120	7.1 %	320	60	7.7 %	320
DODGE	600	3	78	13.0 %	382	55	15.4 %	249
FORD	Granada	3	106	8.8 %	427	60	7.7 %	471
FORD	Tempo	3	114	14.8 %	391	51	21.5 %	409
FORD	Thunderbird	3	100	21.7 %	543	56	13.8 %	391
HONDA	Prelude	3	96	7.5 %	458	53	18.5 %	334
ISUZU	Impulse	3	102	25.4 %	351	54	16.9 %	196
MAZDA-TOYO-KOGYO	626D	3	110	13.9 %	534	50	23.1 %	267
MITSUBISHI	Starion	3	126	12.8 %	516	50	23.1 %	503
MITSUBISHI	Tredia	3	98	16.7 %	445	52	20.0 %	338
NISSAN	Pulsar	3	82	20.0 %	445	48	26.2 %	382
PLYMOUTH	Horizon	3	119	15.9 %	498	67	-3.1 %	294
SUBARU	DL	3	68	29.1 %	516	53	18.5 %	285
TOYOTA	Camry	3	124	15.1 %	494	50	23.1 %	409
TOYOTA	Cressida	3	108	17.4 %	498	51	21.5 %	462
VOLKSWAGEN	Rabbit	3	90	23.5 %	516	51	21.5 %	516
VOLVO	GL	3	118	19.3 %	254	53	18.5 %	209
CHEVROLET	Cavalier	4	112	13.3 %	338	57	12.3 %	249
DODGE	600	4	76	15.2 %	249	54	16.9 %	178
FORD	Tempo	4	122	8.8 %	538	55	15.4 %	302
FORD	Thunderbird	4	--		--	--	--	--
HONDA	Prelude	4	83	20.0 %	462	52	20.0 %	196
ISUZU	Impulse	4	109	20.3 %	480	54	16.9 %	418
MAZDA-TOYO-KOGYO	626D	4	111	13.1 %	445	51	21.5 %	422
MITSUBISHI	Tredia	4	105	10.7 %	480	54	16.9 %	249
NISSAN	Pulsar	4	78	23.9 %	409	48	26.2 %	249
SUBARU	DL	4	74	22.9 %	498	53	18.5 %	329
TOYOTA	Camry	4	132	9.7 %	512	50	23.1 %	356
TOYOTA	Cressida	4	112	14.3 %	494	52	20.0 %	405
VOLVO	GL	4	114	22.0 %	427	52	20.0 %	262

MANUFACTURER	MODEL	REP NO.	LLVW HIGH SPEED EFF. m	%PASS -FAIL	MAX. PEDAL FORCE N	GVWR ENG OFF EFF. m	%PASS -FAIL	MAX. PEDAL FORCE N
CHEVROLET	Cavalier	1	98	24.2 %	302	73	-1.4 %	258
CHEVROLET	Celebrity	1	103	20.3 %	240	67	6.9 %	285
CHEVROLET	Citation #1	1	107	15.3 %	196	69	4.2 %	196
CHEVROLET	Citation #2	1	107	15.3 %	169	66	8.3 %	294
CHEVROLET	Citation #3	1	110	12.9 %	196	68	5.6 %	249
CHRYSLER	Cordoba	1	77	24.9 %	334	60	16.7 %	245
DODGE	Colt	1	70	31.7 %	338	69	4.2 %	462
DODGE	Diplomat Wgn	1	82	22.0 %	329	62	13.9 %	311
FORD	EXP	1	94	21.0 %	445	62	13.9 %	409
FORD	Mustang	1	98	16.7 %	205	63	12.5 %	267
HONDA	Civic	1	60	30.2 %	356	66	8.3 %	480
MAZDA	RX-7	1	125	25.3 %	178	55	23.6 %	214
MERCURY	Marquis Wgn	1	92	13.6 %	267	66	8.3 %	311
NISSAN	Sentra	1	75	21.8 %	178	65	9.7 %	338
OLDSMOBILE	Cruiser Wgn	1	106	18.0 %	222	61	15.3 %	267
OLDSMOBILE	Toronado	1	73	24.9 %	214	118	-63.9 %	498
PLYMOUTH	Gran Fury	1	76	21.8 %	249	71	1.4 %	285
PLYMOUTH	Horizon	1	100	-1.5 %	196	62	13.9 %	267
RENAULT	18i	1	74	23.9 %	298	64	11.1 %	302
TOYOTA	Cressida	1	97	25.8 %	302	54	25.0 %	454
TOYOTA	Starlet	1	74	27.8 %	418	56	22.2 %	471
VOLKSWAGEN	Rabbit	1	92	21.8 %	214	61	15.3 %	231
VOLVO	244	1	107	26.8 %	196	64	11.1 %	249
CHEVROLET	Citation#1w/B	1	101	20.0 %	338	70	2.8 %	480
FORD	Mustang w/B	1	89	24.3 %	360	57	20.8 %	409
NISSAN	Sentra w/B	1	71	26.0 %	240	64	11.1 %	391
OLDSMOBILE	Cruis Wgn w/B	1	105	18.7 %	227	69	4.2 %	196
FORD	EXP/Escort	2	109	8.4 %	498	74	-2.8 %	534
FORD	Granada/LTD	2	82	17.9 %	320	63	12.5 %	311
NISSAN	Sentra	2	69	28.1 %	356	60	16.7 %	365
PLYMOUTH	Horizon	2	104	26.5 %	214	54	25.0 %	267
BMW	735i	3	121	38.2 %	498	56	22.2 %	173
CHEVROLET	Caprice Clas	3	103	13.5 %	227	71	1.4 %	289
CHEVROLET	Cavalier	3	99	23.4 %	267	68	5.6 %	302
DODGE	600	3	68	24.1 %	267	52	27.8 %	285
FORD	Granada	3	100	13.9 %	378	66	8.3 %	485
FORD	Tempo	3	95	29.0 %	365	61	15.3 %	454
FORD	Thunderbird	3	100	21.7 %	338	64	11.1 %	462
HONDA	Prelude	3	77	25.8 %	387	63	12.5 %	454
ISUZU	Impulse	3	97	29.1 %	311	57	20.8 %	476
MAZDA-TOYO-KOGYO	626D	3	97	24.1 %	218	58	19.4 %	445
MITSUBISHI	Starion	3	104	28.1 %	534	56	22.2 %	552
MITSUBISHI	Tredia	3	89	24.3 %	276	61	15.3 %	320
NISSAN	Pulsar	3	72	29.7 %	374	55	23.6 %	418
PLYMOUTH	Horizon	3	114	19.4 %	267	64	11.1 %	285
SUBARU	DL	3	73	23.9 %	338	52	27.8 %	494
TOYOTA	Camry	3	102	30.2 %	445	58	19.4 %	498
TOYOTA	Cressida	3	93	28.9 %	405	59	18.1 %	449
VOLKSWAGEN	Rabbit	3	78	33.7 %	480	85	-18.1 %	516
VOLVO	GL	3	106	27.5 %	209	60	16.7 %	285
CHEVROLET	Cavalier	4	99	23.4 %	338	64	11.1 %	294
DODGE	600	4	69	23.0 %	191	62	13.9 %	302
FORD	Tempo	4	98	26.7 %	302	59	18.1 %	365
FORD	Thunderbird	4	--	--	--	--	--	--
HONDA	Prelude	4	75	27.8 %	249	63	12.5 %	214
ISUZU	Impulse	4	98	28.4 %	498	58	19.4 %	445
MAZDA-TOYO-KOGYO	626D	4	94	26.4 %	294	60	16.7 %	405
MITSUBISHI	Tredia	4	89	24.3 %	267	61	15.3 %	298
NISSAN	Pulsar	4	67	34.6 %	249	55	23.6 %	338
SUBARU	DL	4	68	29.1 %	320	55	23.6 %	498
TOYOTA	Camry	4	100	31.6 %	480	62	13.9 %	494
TOYOTA	Cressida	4	101	22.7 %	342	58	19.4 %	391
VOLVO	GL	4	100	31.6 %	405	60	16.7 %	374

MANUFACTURER	MODEL	REP NO.	LLVW HALF CIR 1 FLD. m	%PASS -FAIL	MAX. PEDAL FORCE N	LLVW HALF CIR 2 FLD. m	%PASS -FAIL	MAX. PEDAL FORCE N
CHEVROLET	Cavalier	1	118	23.9 %	196	121	21.9 %	231
CHEVROLET	Celebrity	1	120	22.6 %	187	124	20.0 %	267
CHEVROLET	Citation #1	1	116	25.2 %	249	120	22.6 %	187
CHEVROLET	Citation #2	1	116	25.2 %	178	115	25.8 %	196
CHEVROLET	Citation #3	1	120	22.6 %	231	117	24.5 %	160
CHRYSLER	Cordoba	1	73	52.9 %	320	132	14.8 %	196
DODGE	Colt	1	108	30.3 %	427	98	36.8 %	325
DODGE	Diplomat Wgn	1	76	51.0 %	285	126	18.7 %	214
FORD	EXP	1	114	26.5 %	525	106	31.6 %	498
FORD	Mustang	1	72	53.5 %	258	139	10.3 %	267
HONDA	Civic	1	91	41.3 %	391	98	36.8 %	351
MAZDA	RX-7	1	74	52.3 %	205	115	25.8 %	498
MERCURY	Marquis Wgn	1	80	48.4 %	302	125	19.4 %	240
NISSAN	Sentra	1	115	25.8 %	178	119	23.2 %	178
OLDSMOBILE	Cruiser Wgn	1	83	46.5 %	169	127	18.1 %	489
OLDSMOBILE	Toronado	1	143	7.7 %	160	66	57.4 %	240
PLYMOUTH	Gran Fury	1	80	48.4 %	267	145	6.5 %	169
PLYMOUTH	Horizon	1	116	25.2 %	231	99	36.1 %	231
RENAULT	18i	1	106	31.6 %	334	102	34.2 %	494
TOYOTA	Cressida	1	131	15.5 %	498	71	54.2 %	249
TOYOTA	Starlet	1	69	55.5 %	391	125	19.4 %	462
VOLKSWAGEN	Rabbit	1	118	23.9 %	196	120	22.6 %	222
VOLVO	244	1	67	56.8 %	196	80	48.4 %	160
CHEVROLET	Citation#1w/B	1	121	21.9 %	160	116	25.2 %	231
FORD	Mustang w/B	1	69	55.5 %	418	134	13.5 %	325
NISSAN	Sentra w/B	1	110	29.0 %	214	113	27.1 %	187
OLDSMOBILE	Cruis Wgn w/B	1	79	49.0 %	187	150	3.2 %	498
FORD	EXP/Escort	2	113	27.1 %	494	115	25.8 %	543
FORD	Granada/LTD	2	77	50.3 %	218	115	25.8 %	480
NISSAN	Sentra	2	105	32.3 %	338	109	29.7 %	227
PLYMOUTH	Horizon	2	106	31.6 %	307	93	40.0 %	218
BMW	735i	3	92	40.6 %	507	89	42.6 %	516
CHEVROLET	Caprice Clas	3	81	47.7 %	338	146	5.8 %	471
CHEVROLET	Cavalier	3	109	29.7 %	214	115	25.8 %	222
DODGE	600	3	120	22.6 %	222	106	31.6 %	205
FORD	Granada	3	84	45.8 %	334	140	9.7 %	320
FORD	Tempo	3	97	37.4 %	276	102	34.2 %	185
FORD	Thunderbird	3	75	51.6 %	325	130	16.1 %	267
HONDA	Prelude	3	110	29.0 %	462	116	25.2 %	365
ISUZU	Impulse	3	71	54.2 %	374	120	22.6 %	409
MAZDA-TOYO-KOGYO	626D	3	103	33.5 %	267	105	32.3 %	231
MITSUBISHI	Starion	3	150	3.2 %	569	74	52.3 %	445
MITSUBISHI	Tredia	3	113	27.1 %	356	113	27.1 %	267
NISSAN	Pulsar	3	106	31.6 %	316	106	31.6 %	360
PLYMOUTH	Horizon	3	116	25.2 %	462	98	36.8 %	320
SUBARU	DL	3	107	31.0 %	302	105	32.3 %	503
TOYOTA	Camry	3	103	33.5 %	480	100	35.5 %	471
TOYOTA	Cressida	3	129	16.8 %	498	72	53.5 %	445
VOLKSWAGEN	Rabbit	3	110	29.0 %	374	108	30.3 %	480
VOLVO	GL	3	70	54.8 %	160	70	54.8 %	160
CHEVROLET	Cavalier	4	111	28.4 %	276	110	29.0 %	254
DODGE	600	4	115	25.8 %	138	109	29.7 %	142
FORD	Tempo	4	112	27.7 %	280	105	32.3 %	302
FORD	Thunderbird	4	--	--	--	--	--	--
HONDA	Prelude	4	93	40.0 %	249	100	35.5 %	231
ISUZU	Impulse	4	70	54.8 %	462	120	22.6 %	374
MAZDA-TOYO-KOGYO	626D	4	95	38.7 %	258	97	37.4 %	178
MITSUBISHI	Tredia	4	118	23.9 %	231	116	25.2 %	231
NISSAN	Pulsar	4	97	37.4 %	391	101	34.8 %	307
SUBARU	DL	4	100	35.5 %	498	107	31.0 %	498
TOYOTA	Camry	4	99	36.1 %	347	99	36.1 %	347
TOYOTA	Cressida	4	134	13.5 %	494	73	52.9 %	356
VOLVO	GL	4	71	54.2 %	209	71	54.2 %	276

MANUFACTURER	MODEL	REP NO.	GVWR HALF CIR 1 FLD. m	%PASS -FAIL	MAX. PEDAL FORCE N	GVWR HALF CIR 2 FLD. m	%PASS -FAIL	MAX. PEDAL FORCE N
CHEVROLET	Cavalier	1	136	12.3 %	222	136	12.3 %	262
CHEVROLET	Celebrity	1	145	6.5 %	231	148	4.5 %	329
CHEVROLET	Citation #1	1	138	11.0 %	249	146	5.8 %	214
CHEVROLET	Citation #2	1	131	15.5 %	276	133	14.2 %	231
CHEVROLET	Citation #3	1	135	12.9 %	231	144	7.1 %	222
CHRYSLER	Cordoba	1	95	38.7 %	262	118	23.9 %	462
DODGE	Colt	1	128	17.4 %	480	134	13.5 %	480
DODGE	Diplomat Wgn	1	94	39.4 %	338	118	23.9 %	498
FORD	EXP	1	125	19.4 %	498	119	23.2 %	498
FORD	Mustang	1	84	45.8 %	205	140	9.7 %	516
HONDA	Civic	1	108	30.3 %	480	110	29.0 %	480
MAZDA	RX-7	1	72	53.5 %	240	111	28.4 %	320
MERCURY	Marquis Wgn	1	92	40.6 %	320	122	21.3 %	409
NISSAN	Sentra	1	142	8.4 %	183	140	9.7 %	185
OLDSMOBILE	Cruiser Wgn	1	96	38.1 %	214	141	9.0 %	498
OLDSMOBILE	Toronado	1	119	23.2 %	249	73	52.9 %	285
PLYMOUTH	Gran Fury	1	97	37.4 %	374	125	19.4 %	320
PLYMOUTH	Horizon	1	137	11.6 %	249	123	20.6 %	302
RENAULT	18i	1	99	36.1 %	485	106	31.6 %	480
TOYOTA	Cressida	1	139	10.3 %	489	80	48.4 %	258
TOYOTA	Starlet	1	79	49.0 %	382	156	-0.6 %	489
VOLKSWAGEN	Rabbit	1	132	14.8 %	214	127	18.1 %	231
VOLVO	244	1	64	58.7 %	462	75	51.6 %	249
CHEVROLET	Citation#1w/B	1	132	14.8 %	391	143	7.7 %	382
FORD	Mustang w/B	1	76	51.0 %	489	136	12.3 %	507
NISSAN	Sentra w/B	1	129	16.8 %	196	134	13.5 %	178
OLDSMOBILE	Cruis Wgn w/B	1	92	40.6 %	227	149	3.9 %	498
FORD	EXP/Escort	2	151	2.6 %	525	150	3.2 %	494
FORD	Granada/LTD	2	85	45.2 %	498	130	16.1 %	511
NISSAN	Sentra	2	128	17.4 %	285	127	18.1 %	262
PLYMOUTH	Horizon	2	122	21.3 %	427	114	26.5 %	356
BMW	735i	3	91	41.3 %	525	92	40.6 %	534
CHEVROLET	Caprice Clas	3	102	34.2 %	116	151	2.6 %	512
CHEVROLET	Cavalier	3	136	12.3 %	267	132	14.8 %	267
DODGE	600	3	129	16.8 %	249	120	22.6 %	209
FORD	Granada	3	93	40.0 %	543	134	13.5 %	489
FORD	Tempo	3	122	21.3 %	391	124	20.0 %	267
FORD	Thunderbird	3	81	47.7 %	267	137	11.6 %	556
HONDA	Prelude	3	123	20.6 %	302	116	25.2 %	231
ISUZU	Impulse	3	74	52.3 %	498	115	25.8 %	512
MAZDA-TOYO-KOGYO	626D	3	115	25.8 %	480	117	24.5 %	400
MITSUBISHI	Starion	3	167	-7.7 %	516	91	41.3 %	485
MITSUBISHI	Tredia	3	124	20.0 %	498	118	23.9 %	498
NISSAN	Pulsar	3	125	19.4 %	320	131	15.5 %	462
PLYMOUTH	Horizon	3	133	14.2 %	378	116	25.2 %	445
SUBARU	DL	3	118	23.9 %	516	123	20.6 %	552
TOYOTA	Camry	3	113	27.1 %	489	117	24.5 %	374
TOYOTA	Cressida	3	151	2.6 %	498	78	49.7 %	498
VOLKSWAGEN	Rabbit	3	133	14.2 %	480	122	21.3 %	498
VOLVO	GL	3	66	57.4 %	205	66	57.4 %	249
CHEVROLET	Cavalier	4	129	16.8 %	258	132	14.8 %	240
DODGE	600	4	128	17.4 %	182	121	21.9 %	196
FORD	Tempo	4	131	15.5 %	338	128	17.4 %	356
FORD	Thunderbird	4	--	--	--	--	--	--
HONDA	Prelude	4	113	27.1 %	222	111	28.4 %	316
ISUZU	Impulse	4	76	51.0 %	476	113	27.1 %	431
MAZDA-TOYO-KOGYO	626D	4	114	26.5 %	391	115	25.8 %	351
MITSUBISHI	Tredia	4	130	16.1 %	391	129	16.8 %	382
NISSAN	Pulsar	4	114	26.5 %	360	113	27.1 %	391
SUBARU	DL	4	116	25.2 %	489	117	24.5 %	589
TOYOTA	Camry	4	121	21.9 %	503	124	20.0 %	356
TOYOTA	Cressida	4	155	0.0 %	512	82	47.1 %	458
VOLVO	GL	4	66	57.4 %	396	69	55.5 %	338

MANUFACTURER	MODEL	REP NO.	POWER ASSIS FLD. m	%PASS -FAIL	MAX. PEDAL FORCE N	BASE LINE m	AVG. PEDAL FORCE N	HOT PERF EFF. m	%PASS -FAIL	MAX. PEDAL FORCE N
CHEVROLET	Cavalier	1	129	16.8 %	498	--	--	68	25.3 %	494
CHEVROLET	Celebrity	1	156	-0.6 %	480	--	--	72	20.9 %	454
CHEVROLET	Citation #1	1	178	-14.8 %	498	--	--	73	19.8 %	480
CHEVROLET	Citation #2	1	148	4.5 %	552	--	--	71	22.0 %	374
CHEVROLET	Citation #3	1	158	-1.9 %	507	--	--	63	30.8 %	516
CHRYSLER	Cordoba	1	157	-1.3 %	507	--	--	77	15.4 %	440
DODGE	Colt	1	101	34.8 %	489	--	--	78	14.3 %	480
DODGE	Diplomat Wgn	1	197	-27.1 %	516	--	--	79	13.2 %	391
FORD	EXP	1	167	-7.7 %	498	--	--	82	9.9 %	498
FORD	Mustang	1	97	37.4 %	516	--	--	72	20.9 %	462
HONDA	Civic	1	70	54.8 %	485	--	--	70	23.1 %	485
MAZDA	RX-7	1	64	58.7 %	498	--	--	58	36.3 %	396
MERCURY	Marquis Wgn	1	191	-23.2 %	516	--	--	81	11.0 %	480
NISSAN	Sentra	1	85	45.2 %	480	--	--	72	20.9 %	249
OLDSMOBILE	Cruiser Wgn	1	183	-18.1 %	498	--	--	67	26.4 %	489
OLDSMOBILE	Toronado	1	141	9.0 %	516	--	--	81	11.0 %	498
PLYMOUTH	Gran Fury	1	163	-5.2 %	498	--	--	77	15.4 %	498
PLYMOUTH	Horizon	1	90	41.9 %	507	--	--	82	9.9 %	445
RENAULT	18i	1	110	29.0 %	489	--	--	69	24.2 %	471
TOYOTA	Cressida	1	98	36.8 %	489	--	--	67	26.4 %	480
TOYOTA	Starlet	1	65	58.1 %	480	--	--	73	19.8 %	480
VOLKSWAGEN	Rabbit	1	82	47.1 %	489	--	--	92	-1.1 %	329
VOLVO	244	1	116	25.2 %	498	--	--	61	33.0 %	347
CHEVROLET	Citation#1w/B	1	171	-10.3 %	498	--	--	67	26.4 %	467
FORD	Mustang w/B	1	130	16.1 %	516	--	--	78	14.3 %	498
NISSAN	Sentra w/B	1	82	47.1 %	498	--	--	77	15.4 %	285
OLDSMOBILE	Cruis Wgn w/B	1	185	-19.4 %	525	--	--	70	23.1 %	489
FORD	EXP/Escort	2	NA	ERR %	--	--	--	105	-15.4 %	--
FORD	Granada/LTD	2	120	22.6 %	494	--	--	75	17.6 %	--
NISSAN	Sentra	2	105	32.3 %	516	--	--	66	27.5 %	--
PLYMOUTH	Horizon	2	79	49.0 %	498	--	--	83	6.0 %	--
BMW	735i	3	84	45.8 %	498	45	462	46	40.0 %	--
CHEVROLET	Caprice Clas	3	164	-5.8 %	498	66	142	85	6.6 %	--
CHEVROLET	Cavalier	3	129	16.8 %	512	65	178	84	7.7 %	--
DODGE	600	3	129	16.8 %	516	58	178	78	14.3 %	--
FORD	Granada	3	149	3.9 %	525	59	400	83	8.8 %	--
FORD	Tempo	3	96	38.1 %	534	58	205	74	18.7 %	--
FORD	Thunderbird	3	112	27.7 %	618	58	271	74	18.7 %	--
HONDA	Prelude	3	69	55.5 %	480	60	360	93	-2.2 %	--
ISUZU	Impulse	3	85	45.2 %	529	55	267	62	31.9 %	--
MAZDA-TOYO-KOGYO	626D	3	109	29.7 %	498	61	258	76	16.5 %	--
MITSUBISHI	Starion	3	94	39.4 %	574	57	445	71	22.0 %	--
MITSUBISHI	Tredia	3	88	43.2 %	516	60	325	83	8.8 %	--
NISSAN	Pulsar	3	87	43.9 %	552	57	302	68	25.3 %	--
PLYMOUTH	Horizon	3	101	34.8 %	489	62	267	96	-5.5 %	--
SUBARU	DL	3	60	61.3 %	512	51	298	79	7.1 %	--
TOYOTA	Camry	3	117	24.5 %	489	55	387	77	15.4 %	--
TOYOTA	Cressida	3	84	45.8 %	529	54	396	69	23.3 %	--
VOLKSWAGEN	Rabbit	3	90	41.9 %	498	59	471	76	16.5 %	--
VOLVO	GL	3	96	38.1 %	498	68	151	70	23.1 %	--
CHEVROLET	Cavalier	4	122	21.3 %	507	64	222	76	16.5 %	--
DODGE	600	4	143	7.7 %	503	61	156	78	14.3 %	--
FORD	Tempo	4	133	14.2 %	498	62	249	77	15.4 %	--
FORD	Thunderbird	4	--	--	--	--	--	--	--	--
HONDA	Prelude	4	77	50.3 %	529	61	356	72	20.9 %	--
ISUZU	Impulse	4	99	36.1 %	498	58	427	84	7.7 %	--
MAZDA-TOYO-KOGYO	626D	4	107	31.0 %	494	63	249	73	19.8 %	--
MITSUBISHI	Tredia	4	108	30.3 %	512	64	258	81	11.0 %	--
NISSAN	Pulsar	4	79	49.0 %	498	56	298	65	28.6 %	--
SUBARU	DL	4	85	45.2 %	525	56	347	88	3.3 %	--
TOYOTA	Camry	4	126	18.7 %	516	60	285	86	5.5 %	--
TOYOTA	Cressida	4	101	34.8 %	516	60	276	78	14.3 %	--
VOLVO	GL	4	114	26.5 %	498	60	294	69	24.2 %	--

MANUFACTURER	MODEL	REP NO.	REC. EFF. m	%PASS -FAIL	MAX. PEDAL FORCE N	FINAL COLD EFF. m	%PASS -FAIL	MAX. PEDAL FORCE N
CHEVROLET	Cavalier	1	--	--	--	--	--	--
CHEVROLET	Celebrity	1	--	--	--	--	--	--
CHEVROLET	Citation #1	1	--	--	--	--	--	--
CHEVROLET	Citation #2	1	--	--	--	--	--	--
CHEVROLET	Citation #3	1	--	--	--	--	--	--
CHRYSLER	Cordoba	1	--	--	--	--	--	--
DODGE	Colt	1	--	--	--	--	--	--
DODGE	Diplomat Wgn	1	--	--	--	--	--	--
FORD	EXP	1	--	--	--	--	--	--
FORD	Mustang	1	--	--	--	--	--	--
HONDA	Civic	1	--	--	--	--	--	--
MAZDA	RX-7	1	--	--	--	--	--	--
MERCURY	Marquis Wgn	1	--	--	--	--	--	--
NISSAN	Sentra	1	--	--	--	--	--	--
OLDSMOBILE	Cruiser Wgn	1	--	--	--	--	--	--
OLDSMOBILE	Toronado	1	--	--	--	--	--	--
PLYMOUTH	Gran Fury	1	--	--	--	--	--	--
PLYMOUTH	Horizon	1	--	--	--	--	--	--
RENAULT	18i	1	--	--	--	--	--	--
TOYOTA	Cressida	1	--	--	--	--	--	--
TOYOTA	Starlet	1	--	--	--	--	--	--
VOLKSWAGEN	Rabbit	1	--	--	--	--	--	--
VOLVO	244	1	--	--	--	--	--	--
CHEVROLET	Citation#1w/B	1	--	--	--	--	--	--
FORD	Mustang w/B	1	--	--	--	--	--	--
NISSAN	Sentra w/B	1	--	--	--	--	--	--
OLDSMOBILE	Cruis Wgn w/B	1	--	--	--	--	--	--
FORD	EXP/Escort	2	101	-14.0 %	--	--	--	--
FORD	Granada/LTD	2	67	23.1 %	--	--	--	--
NISSAN	Sentra	2	65	28.9 %	--	--	--	--
PLYMOUTH	Horizon	2	76	-0.4 %	--	--	--	--
BMW	735i	3	45	31.5 %	--	--	--	--
CHEVROLET	Caprice Clas	3	79	18.7 %	--	--	--	--
CHEVROLET	Cavalier	3	74	20.3 %	--	--	--	--
DODGE	600	3	68	17.9 %	--	--	--	--
FORD	Granada	3	77	11.6 %	--	--	--	--
FORD	Tempo	3	65	26.6 %	--	--	--	--
FORD	Thunderbird	3	63	25.3 %	--	--	--	--
HONDA	Prelude	3	80	12.5 %	--	--	--	--
ISUZU	Impulse	3	57	31.2 %	--	--	--	--
MAZDA-TOYO-KOGYO	626D	3	70	19.7 %	--	--	--	--
MITSUBISHI	Starion	3	60	35.4 %	--	--	--	--
MITSUBISHI	Tredia	3	64	25.3 %	--	--	--	--
NISSAN	Pulsar	3	67	17.7 %	--	--	--	--
PLYMOUTH	Horizon	3	76	14.2 %	--	--	--	--
SUBARU	DL	3	72	1.2 %	--	--	--	--
TOYOTA	Camry	3	63	19.8 %	--	--	--	--
TOYOTA	Cressida	3	63	18.3 %	--	--	--	--
VOLKSWAGEN	Rabbit	3	62	26.4 %	--	--	--	--
VOLVO	GL	3	61	37.2 %	--	--	--	--
CHEVROLET	Cavalier	4	70	23.4 %	--	67	6.9 %	214
DODGE	600	4	70	23.4 %	--	63	12.5 %	214
FORD	Tempo	4	65	26.6 %	--	64	11.1 %	254
FORD	Thunderbird	4	--	--	--	--	--	--
HONDA	Prelude	4	74	17.8 %	--	58	19.4 %	231
ISUZU	Impulse	4	57	32.4 %	--	57	20.8 %	276
MAZDA-TOYO-KOGYO	626D	4	68	25.6 %	--	61	15.3 %	209
MITSUBISHI	Tredia	4	71	22.3 %	--	64	11.1 %	254
NISSAN	Pulsar	4	60	25.0 %	--	57	20.8 %	231
SUBARU	DL	4	63	22.6 %	--	54	25.0 %	485
TOYOTA	Camry	4	67	21.8 %	--	64	11.1 %	365
TOYOTA	Cressida	4	67	25.6 %	--	61	15.3 %	236
VOLVO	GL	4	68	20.7 %	--	53	26.4 %	294

Car: Chevrolet Cavalier
Reports: 1,3,4

Report #1

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
GVWR Engine Off (Charged)	73 m	Failed by 1.4 %

Test Stop	Max. Pedal Force (N)
Power Assist Failed	498 N
Hot Performance	494 N

* Failed GM Calculated Brake Balance.
* Hot Performance Pedal Force was 240 N greater than Cold Eff.

Report #3

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
1st Effectiveness	65 m	Passed by 0.0 %
2nd Effectiveness	68 m	Failed by 4.6 %

Test Stop	Max. Pedal Force (N)
Power Assist Failed	512 N

* Failed GM Calculated Brake Balance.

Report #4

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
1st Effectiveness	64 m	Passed by 1.5 %
2nd Effectiveness	64 m	Passed by 1.5 %

Test Stop	Max. Pedal Force (N)
Power Assist Failed	507 N

* Marginally Failed GM Calculated Brake Balance.

Car: Chevrolet Celebrity
Reports: 1

Report #1

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
GVWR High Speed	125 m	Passed by 3.3 %
GVWR Half Circuit 2	148 m	Passed by 4.5 %
Power Assist Failed	156 m	Failed by 0.6 %

Test Stop	Max. Pedal Force (N)
Power Assist Failed	507 N

* Failed GM Calculated Brake Balance.
* Failed NHTSA Adhesion Utilization Curve.

Car: Chevrolet Citation #1
Reports: 1,1b

Report #1

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
GVWR Engine Off (Charged)	69 m	Passed by 4.2 %
Power Assist Failed	178 m	Failed by 14.8 %

Test Stop	Max. Pedal Force (N)
Power Assist Failed	498 N

* Failed GM Calculated Brake Balance.
* Hot Performance Pedal Force was 231 N greater than Cold Eff.

Report #1b

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
1st Effectiveness	65 m	Passed by 0.0 %
GVWR Engine Off (Charged)	70 m	Passed by 2.8 %
Power Assist Failed	171 m	Failed by 10.3 %

Test Stop	Max. Pedal Force (N)
Power Assist Failed	498 N

* Failed GM Calculated Brake Balance.
* Hot Performance Pedal Force was 5 N greater than Cold Eff.

Car: Chevrolet Citation #2
Reports: 1

Report #1

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
Pre-Burnish Effectiveness	69 m	Passed by 4.2 %
Power Assist Failed	148 m	Passed by 4.5 %

Test Stop	Max. Pedal Force (N)
Power Assist Failed	552 N

* Failed GM Calculated Brake Balance.
* Hot Performance Pedal Force was 98 N greater than Cold Eff.

Car: Chevrolet Citation #3
Reports: 1

Report #1

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
Power Assist Failed	158 m	Failed by 1.9 %

Test Stop	Max. Pedal Force (N)
Power Assist Failed	507 N
Hot Performance	516 N

* Failed GM Calculated Brake Balance.
* Hot Performance Pedal Force was 62 N greater than Cold Eff.

Car: Chrysler Cordoba
Reports: 1

Report #1

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
Power Assist Failed	157 m	Failed by 1.3 %

Test Stop	Max. Pedal Force (N)
Power Assist Failed	507 N

* Failed GM Calculated Brake Balance.
* Failed NHTSA Adhesion Utillization Curve.
* Hot Performance Pedal Force was 169 N greater than Cold Eff.

Car: Dodge Colt
Reports: 1

Report #1

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
GVWR High Speed	99 m	Passed by 3.4 %
GVWR Engine Off (Charged)	69 m	Passed by 4.2 %

Car: Dodge Diplomat Wagon
Reports: 1

Report #1

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
Power Assist Failed	197 m	Failed by 27.1 %

Test Stop	Max. Pedal Force (N)
GVWR Half Circuit 2	498 N
Power Assist Failed	516 N

* Failed GM Calculated Brake Balance.
* Hot Performance Pedal Force was 89 N greater than Cold Eff.

Car: Ford EXP
Reports: 1

Report #1

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
Pre-Burnish Effectiveness	70 m	Passed by 2.8 %
Power Assist Failed	167 m	Failed by 7.7 %

Test Stop	Max. Pedal Force (N)
LLVW Half Circuit 1	525 N
LLVW Half Circuit 2	498 N
GVWR Half Circuit 1	498 N
GVWR Half Circuit 2	498 N
Power Assist Failed	498 N
Hot Performance	498 N

* Failed GM Calculated Brake Balance.
* Hot Performance Pedal Force was 240 N greater than Cold Eff.

Car: Ford Mustang
Reports: 1,1b

Report #1

Test Stop	Max. Pedal Force (N)
GVWR Half Circuit 2	516 N
Power Assist Failed	516 N

* Failed GM Calculated Brake Balance.
* Hot Performance Pedal Force was 160 N greater than Cold Eff.

Report #1b

Test Stop	Max. Pedal Force (N)
GVWR High Speed	498 N
GVWR Half Circuit 2	507 N
Power Assist Failed	516 N
Hot Performance	498 N

* Failed GM Calculated Brake Balance.
* Hot Performance Pedal Force was 124 N greater than Cold Eff.

Car: Honda Civic
Reports: 1

Report #1

* Marginally Failed GM Calculated Brake Balance.

Car: Mazda RX-7
Reports: 1

Report #1

Test Stop	Max. Pedal Force (N)
LLVW Half Circuit 2	498 N
Power Assist Failed	498 N

* Hot Performance Pedal Force was 147 N greater than Cold Eff.

Car: Mercury Marquis Wagon
Reports: 1

Report #1

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
Power Assist Failed	191 m	Failed by 23.2 %

Test Stop	Max. Pedal Force (N)
Power Assist Failed	516 N

* Failed GM Calculated Brake Balance.
* Hot Performance Pedal Force was 249 N greater than Cold Eff.

Car: Nissan Sentra
Reports: 1,1b,2

Report #1

* Failed GM Calculated Brake Balance.
* Hot Performance Pedal Force was 18 N greater than Cold Eff.

Report #1b

Test Stop	Max. Pedal Force (N)
Power Assist Failed	498 N

* Marginally Failed GM Calculated Brake Balance.

Report #2

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
1st Effectiveness	64 m	Passed by 1.5 %

Test Stop	Max. Pedal Force (N)
Power Assist Failed	516 N

Car: Oldsmobile Cruiser Wagon
Reports: 1,1b

Report #1

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
Pre-Burnish Effectiveness	183 m	Failed by 18.1 %

Test Stop	Max. Pedal Force (N)
GVWR Half Circuit 2	498 N
Power Assist Failed	498 N

* Failed GM Calculated Brake Balance.
* Hot Performance Pedal Force was 258 N greater than Cold Eff.

Report #1b

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
1st Effectiveness	62 m	Passed by 4.6 %
GVWR High Speed	125 m	Passed by 3.3 %
GVWR Engine Off (Charged)	69 m	Passed by 4.2 %
LLVW Half Ciruit 2	150 m	Passed by 3.2 %
GVRW Half Ciruit 2	149 m	Passed by 3.9 %
Power Assist Failed	167 m	Failed by 19.4 %

Test Stop	Max. Pedal Force (N)
LLVW Half Circuit 2	498 N
GVWR Half Circuit 2	498 N
Power Assist Failed	525 N

* Failed GM Calculated Brake Balance.
* Hot Performance Pedal Force was 231 N greater than Cold Eff.

Car: Oldsmobile Toronado
Reports: 1

Report #1

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
GVRW Engine Off (Charged)	118 m	Failed by 63.9 %

Test Stop	Max. Pedal Force (N)
GVWR Engine Off (Charged)	498 N
Power Assist Failed	516 N
Hot Performance	498 N

* Failed GM Calculated Brake Balance.
* Hot Performance Pedal Force was 160 N greater than Cold Eff.

Appendix 14

Car: Plymouth Gran Fury
Reports: 1

Report #1

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
GVWR Engine Off (Charged)	71 m	Passed by 1.4 %
Power Assist Failed	153 m	Failed by 5.2 %

Test Stop	Max. Pedal Force (N)
Power Assist Failed	498 N
Hot Performance	498 N

* Failed GM Calculated Brake Balance.
* Hot Performance Pedal Force was 240 N greater than Cold Eff.

Appendix 14

Car: Plymouth Horizon
Reports: 1,2,3

Report #1

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
GVRW High Speed	132 m	Failed by 34.0 %
LLVW Half Circuit 1	116 m	Failed by 1.6 %

Test Stop	Max. Pedal Force (N)
Power Assist Failed	507 N

* Failed GM Calculated Brake Balance.
* Hot Performance Pedal Force was 143 N greater than Cold Eff.

Report #2

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
Recovery Effectiveness	76 m	Failed by 0.4 %

Report #3

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
1st Effectiveness	62 m	Passed by 4.6 %
LLVW Cold Effectiveness	67 m	Failed by 3.1 %
Hot Perfomance	96 m	Failed by 5.5 %

Test Stop	Max. Pedal Force (N)
GVWR High Speed	498 N

* Failed GM Calculated Brake Balance.

Car: Renault 18i
Reports: 1

Report #1

* Failed GM Calculated Brake Balance.
* Failed NHTSA Adhesion Utilization Curve.

Car: Toyota Cressida
Reports: 1,3,4

Report #1

Test Stop	Max. Pedal Force (N)
Pre-Burnish Effectiveness	507 N
GVWR High Speed	498 N
LLVW Half Circuit 1	498 N

* Failed GM Calculated Brake Balance.

Report #3

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
GVWR Half Circuit 1	151 m	Passed by 2.6 %

Test Stop	Max. Pedal Force (N)
1st Effectiveness	516 N
GVWR High Speed	498 N
LLVW Half Circuit 1	498 N
GVWR Half Circuit 1	498 N
GVWR Half Circuit 2	498 N
Power Assist Failed	529 N

* Failed NHTSA Adhesion Utilization Curve.

Report #4

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
1st Effectiveness	63 m	Passed by 3.1 %
GVWR Half Circuit 1	155 m	Passed by 0.0 %

Test Stop	Max. Pedal Force (N)
GVWR High Speed	494 N
LLVW Half Circuit 1	494 N
GVWR Half Circuit 1	512 N
Power Assist Failed	516 N

Car: Toyota Starlet
Reports: 1

Report #1

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
GVWR Half Circuit 1	156 m	Failed by 0.6 %

Test Stop	Max. Pedal Force (N)
GVWR High Speed	605 N
GVWR Half Circuit 2	498 N
Power Assist Failed	498 N
Hot Performance	498 N

* Failed GM Calculated Brake Balance.
* Hot Performance Pedal Force was 26 N greater than Cold Eff.

Car: Volkswagen Rabbit
Reports: 1,3

Report #1

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
Hot Performance	92 m	Failed by 1.1 %

* Marginally Failed GM Calculated Brake Balance.

Report #3

Test Stop	Max. Pedal Force (N)
1st Effectiveness	560 N
2nd Effectiveness	649 N
GVWR High Speed	516 N
LLVW Cold Effectiveness	516 N
GVWR Engine Off	516 N
GVWR Half Circuit 2	498 N
Power Assist Failed	498 N

Car: Volvo 244
Reports: 1

Report #1

Test Stop	Max. Pedal Force (N)
GVWR High Speed	552 N
Power Assist Failed	498 N

* Marginally Failed GM Calculated Brake Balance.

Car: Ford EXP/Escort
Reports: 2

Report #2

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
1st Effectiveness	62 m	Passed by 4.6 %
2nd Effectiveness	63 m	Passed by 3.1 %
GVWR High Speed	118 m	Passed by 0.9 %
LLVW Cold Effectiveness	64 m	Passed by 1.5 %
GVWR Engine Off (Charged)	74 m	Failed by 2.8 %
GVWR Half Circuit 1	151 m	Passed by 2.6 %
GVWR Half Circuit 2	150 m	Passed by 3.2 %
Hot Performance	105 m	Passed by 15.4 %
Recovery Effectiveness	101 m	Failed by 14.0 %

Test Stop	Max. Pedal Force (N)
1st Effectiveness	494 N
2nd Effectiveness	516 N
GVWR High Speed	498 N
LLVW Cold Effectiveness	498 N
LLVW High Speed	498 N
GVWR Engine Off (Charged)	534 N
LLVW Half Circuit 1	494 N
LLVW Half Circuit 2	543 N
GVWR Half Circuit 1	525 N
GVWR Half Circuit 2	494 N

* Failed GM Calculated Brake Balance.

Car: Ford Granada/LTD
Reports: 2,3

Report #2

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
LLVW Cold Effectiveness	62 m	Passed by 4.6 %

Test Stop	Max. Pedal Force (N)
GVWR Half Circuit 1	498 N
GVWR Half Circuit 2	511 N
Power Assist	494 N

* Failed GM Calculated Brake Balance.

Report #3

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
Power Assist	149 m	Passed by 3.9 %

Test Stop	Max. Pedal Force (N)
1st Effectiveness	538 N
GVWR Half Circuit 1	543 N
Power Assist	525 N

* Failed GM Calculated Brake Balance.
* Failed NHTSA Adhesion Utilization Curve.

Car: BMW 735i
Reports: 3

Report #3

Test Stop	Max. Pedal Force (N)
1st Effectiveness	552 N
2nd Effectiveness	552 N
GVWR High Speed	534 N
LLVW High Speed	498 N
LLVW Half Circuit 1	507 N
LLVW Half Circuit 2	516 N
GVWR Half Circuit 1	525 N
GVWR Half Circuit 2	534 N
Power Assist Failed	498 N

Car: Caprice Classic
Reports: 3

Report #3

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
1st Effectiveness	68 m	Failed by 4.6 %
2nd Effectiveness	66 m	Failed by 1.5 %
GVWR High Speed	116 m	Passed by 2.5 %
GVWR Engine Off (Charged)	71 m	Passed by 1.4 %
GVWR Half Circuit 2	151 m	Passed by 2.6 %
Recovery Effectiveness	164 m	Failed by 5.8 %

Test Stop	Max. Pedal Force (N)
GVWR Half Circuit 2	512 N
Power Assist Failed	498 N

* Failed GM Calculated Brake Balance.
* Failed NHTSA Adhesion Utilization Curve.

Car: Dodge 600
Reports: 3,4

Report #3

Test Stop	Max. Pedal Force (N)
Power Assist Failed	516 N

* Marginally Failed GM Calculated Brake Balance.

Report #4

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
1st Effectiveness	64 m	Passed by 1.5 %

Test Stop	Max. Pedal Force (N)
Power Assist Failed	503 N

* Marginally Failed GM Calculated Brake Balance.

Car: Ford Tempo
Reports: 3,4

Report #3

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
1st Effectiveness	62 m	Passed by 4.6 %

Test Stop	Max. Pedal Force (N)
Power Assist Failed	534 N

* Failed NHTSA Adhesion Utilization Curve.

Report #4

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
1st Effectiveness	62 m	Passed by 4.6 %
2nd Effectiveness	64 m	Passed by 1.5 %

Test Stop	Max. Pedal Force (N)
GVWR High Speed	538 N
Power Assist Failed	498 N

* Marginally Failed GM Calculated Brake Balance.

Car: Ford Thunderbird
Reports: 3

Report #3

Test Stop	Max. Pedal Force (N)
GVWR High Speed	543 N
GVWR Half Circuit 2	556 N
Power Assist Failed	618 N

* Failed GM Calculated Brake Balance.

Car: Honda Prelude
Reports: 3,4

Report #3

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
1st Effectiveness	64 m	Passed by 1.5 %
Hot Performance	93 m	Failed by 2.2 %

* Failed NHTSA Adhesion Utilization Curve.

Report #4

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
1st Effectiveness	63 m	Passed by 3.1 %

Test Stop	Max. Pedal Force (N)
Power Assist Failed	529 N

Car: Isuzu Impulse
Reports: 3 4

Report #3

Test Stop	Max. Pedal Force (N)
GVWR Half Circuit 1	498 N
GVWR Half Circuit 2	512 N
Power Assist Failed	529 N

* Marginally Failed GM Calculated Brake Balance.
* Failed NHTSA Adhesion Utilization Curve.

Report #4

Test Stop	Max. Pedal Force (N)
Pre-Burnish Effectiveness	516 N
2nd Effectiveness	516 N
GVWR High Speed	498 N
LLVW High Speed	498 N
Power Assist Failed	498 N

* Marginally Failed GM Calculated Brake Balance.

Car: Mazda-Toyo-Kogyo 626D
Reports: 3,4

Report #3

Test Stop	Max. Pedal Force (N)
2nd Effectiveness	534 N
GVWR High Speed	534 N
Power Assist Failed	498 N

Report #4

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
1st Effectiveness	64 m	Passed by 1.5 %
2nd Effectiveness	63 m	Passed by 3.1 %

Test Stop	Max. Pedal Force (N)
Pre-Burnish Effectiveness	494 N
Power Assist Failed	494 N

Car: Mitsubishi Starion
Reports: 3

Report #3

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
1st Effectiveness	65 m	Passed by 0.0 %
LLVW Half Circuit 1	150 m	Passed by 3.2 %
GVWR Half Circuit 1	167 m	Failed by 7.7 %

Test Stop	Max. Pedal Force (N)
1st Effectiveness	498 N
2nd Effectiveness	498 N
GVWR High Speed	516 N
LLVW Cold Effectiveness	503 N
LLVW High Speed	534 N
GVWR Engine Off (Charged)	552 N
LLVW Half Circuit 1	569 N
GVWR Half Circuit 1	516 N
Power Assist Failed	574 N

Car: Mitsubishi Tredia
Reports: 3,4

Report #3

Test Stop	Max. Pedal Force (N)
1st Effectiveness	516 N
GVWR Half Circuit 1	498 N
GVWR Half Circuit 2	498 N
Power Assist Failed	516 N

* Failed NHTSA Adhesion Utilization Curve.

Report #4

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
Pre-Burnish Effectiveness	69 m	Passed by 4.6 %
1st Effectiveness	64 m	Passed by 1.5 %
2nd Effectiveness	66 m	Failed by 1.5 %

Test Stop	Max. Pedal Force (N)
Pre-Burnish Effectiveness	512 N
Power Assist Failed	512 N

Car: Nissan Pulsar
Reports: 3,4

Report #3

Test Stop	Max. Pedal Force (N)
1st Effectiveness	498 N
2nd Effectiveness	498 N
Power Assist Failed	552 N

Report #4

Test Stop	Max. Pedal Force (N)
Power Assist Failed	498 N

Car: Subaru DL
Reports: 3,4

Report #3

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
Recovery Effectiveness	72 m	Passed by 1.2 %

Test Stop	Max. Pedal Force (N)
1st Effectiveness	534 N
2nd Effectiveness	512 N
GVWR High Speed	516 N
GVWR Engine Off (Charged)	494 N
LLVW Half Circuit 2	503 N
GVWR Half Circuit 1	516 N
GVWR Half Circuit 2	552 N
Power Assist Failed	512 N

* Failed NHTSA Adhesion Utilization Curve.

Report #4

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
Hot Performance	88 m	Passed by 3.3 %

Test Stop	Max. Pedal Force (N)
Pre-Burnish Effectiveness	498 N
2nd Effectiveness	498 N
GVWR High Speed	498 N
GVWR Engine Off (Charged)	498 N
LLVW Half Circuit 1	498 N
LLVW Half Circuit 2	498 N
GVWR Half Circuit 2	589 N
Power Assist Failed	525 N

Car: Toyota Camry
Reports: 3,4

Report #3

Test Stop	Max. Pedal Force (N)
1st Effectiveness	498 N
2nd Effectiveness	507 N
GVWR Engine Off (Charged)	498 N

Report #4

Test Stop	Max. Pedal Force (N)
GVWR High Speed	512 N
GVWR Engine Off (Charged)	494 N
GVWR Half Circuit 1	503 N
Power Assist Failed	516 N

Car: Volvo GL
Reports: 3,4

Report #3

Test Stop	Stop Dist. (m)	% Pass/Fail Margin
1st Effectiveness	68 m	Failed by 4.6 %
2nd Effectiveness	68 m	Passed by 4.6 %

Test Stop	Max. Pedal Force (N)
Power Assist Failed	498 N

* Marginally Failed GM Calculated Brake Balance.

Report #4

Test Stop	Max. Pedal Force (N)
Power Assist Failed	498 N

Chevrolet Cavalier Report 1

Wt.(lbs): F=1980 R=1045 T=3025 CG(in)=21.0 WB(in)=100.0 RAD(ft)=0.950

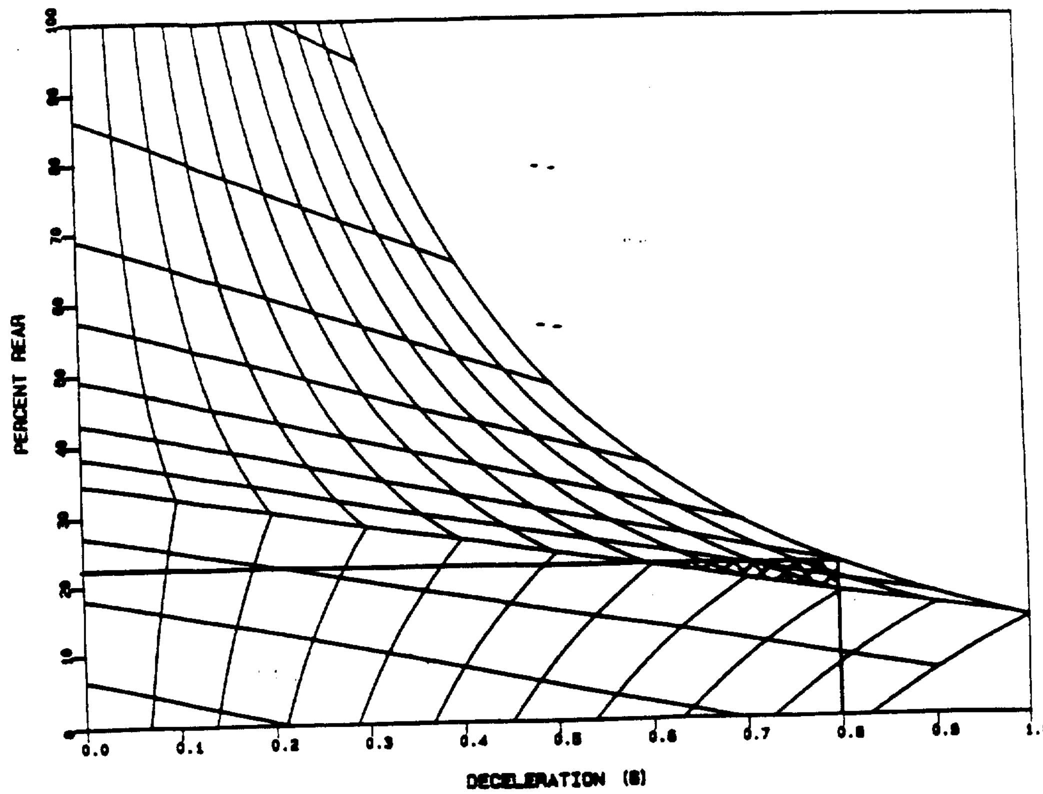


FIGURE 1

Chevrolet Celebrity Report 1

Wt(lbs): F=2070 R=1129 T=3199 CG(in)=21.0 WB(in)=105.0 RAD(ft)=0.950

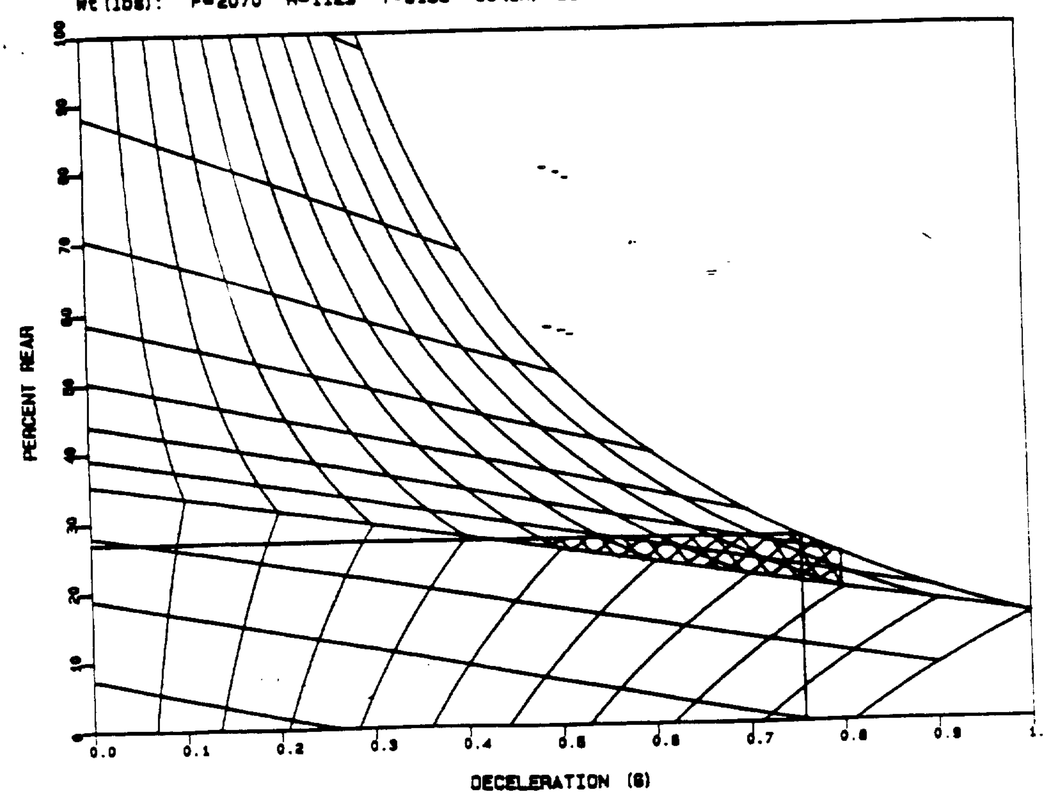


FIGURE 2

Chevrolet Citation Report 1 With Burnish

Wt (lbs): F=1991 R=1135 T=3126 CG (in)=21.0 WB (in)=105.0 RAD (ft)=0.950

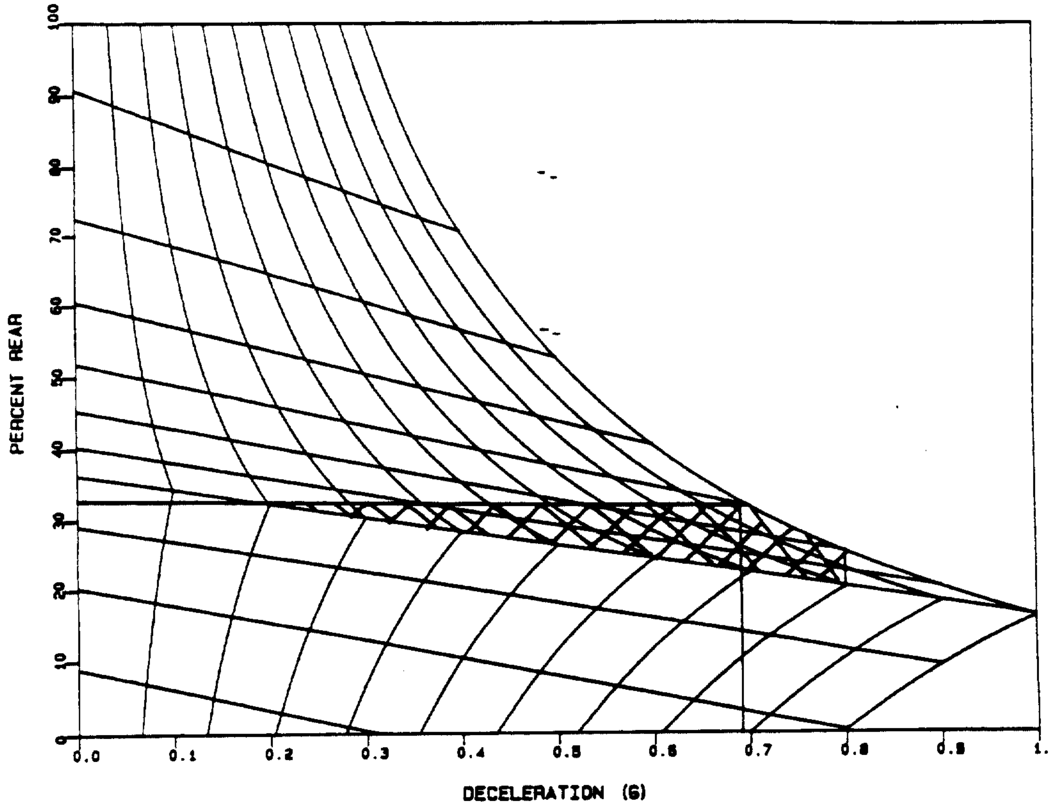


FIGURE 3

Chevrolet Citation Report 1(#2)

Wt (lbs): F=1991 R=1135 T=3126 CG (in)=21.0 WB (in)=105.0 RAD (ft)=0.950

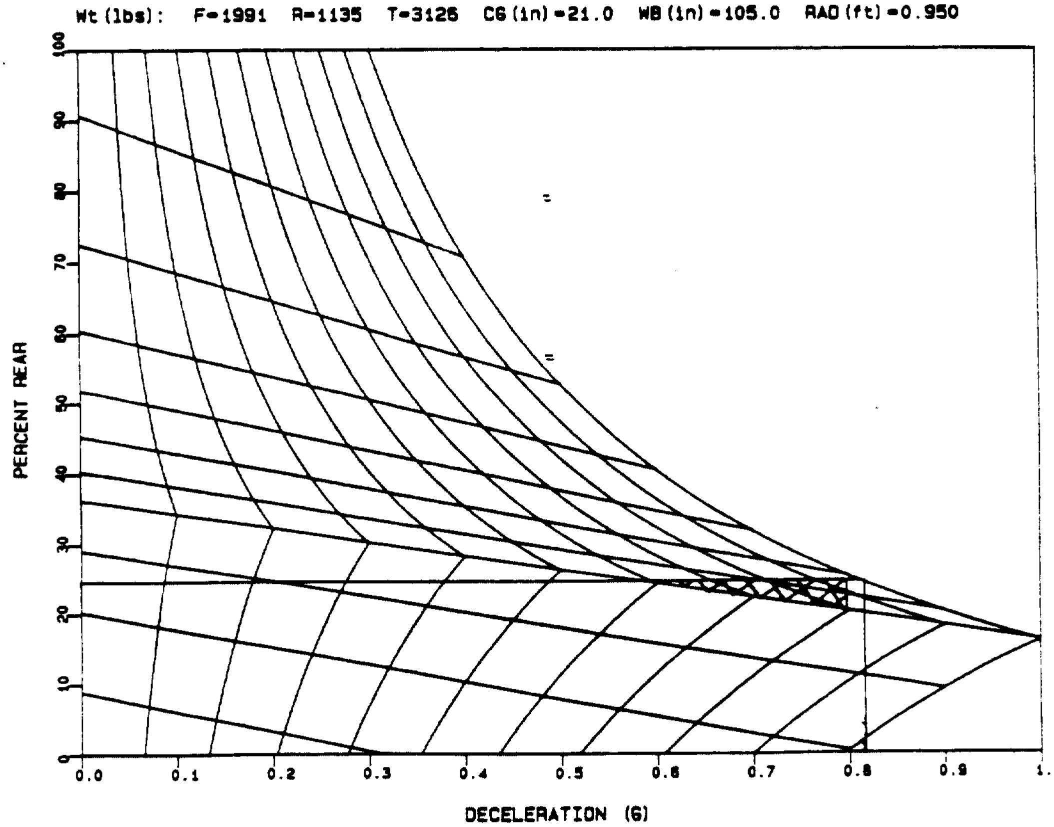


FIGURE 4

Chevrolet Citation Report 1 (#3)

Wt (lbs): F=1991 R=1135 T=3126 CG (in)=21.0 WB (in)=105.0 RAD (ft)=0.950

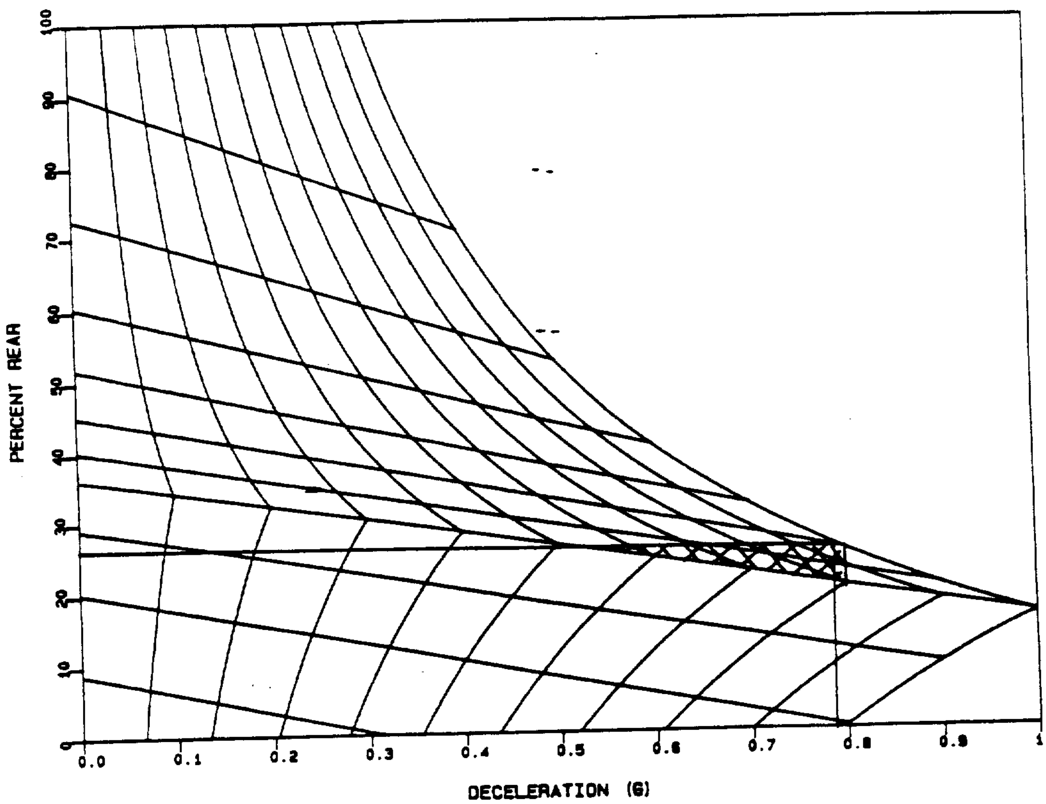


FIGURE 5

Chrysler Cordoba Report 1

Wt (lbs): F=2161 R=1669 T=3830 CG (in)=21.0 WB (in)=113.0 RAD (ft)=0.950

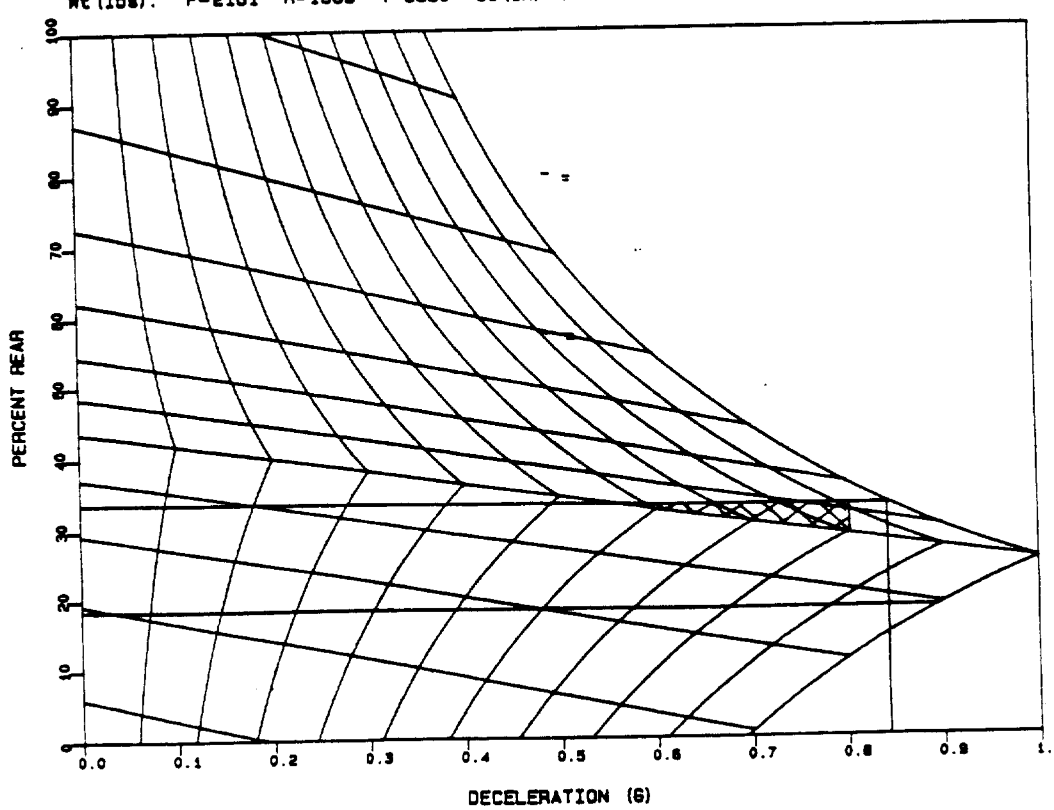


FIGURE 6

Dodge Colt Report 1

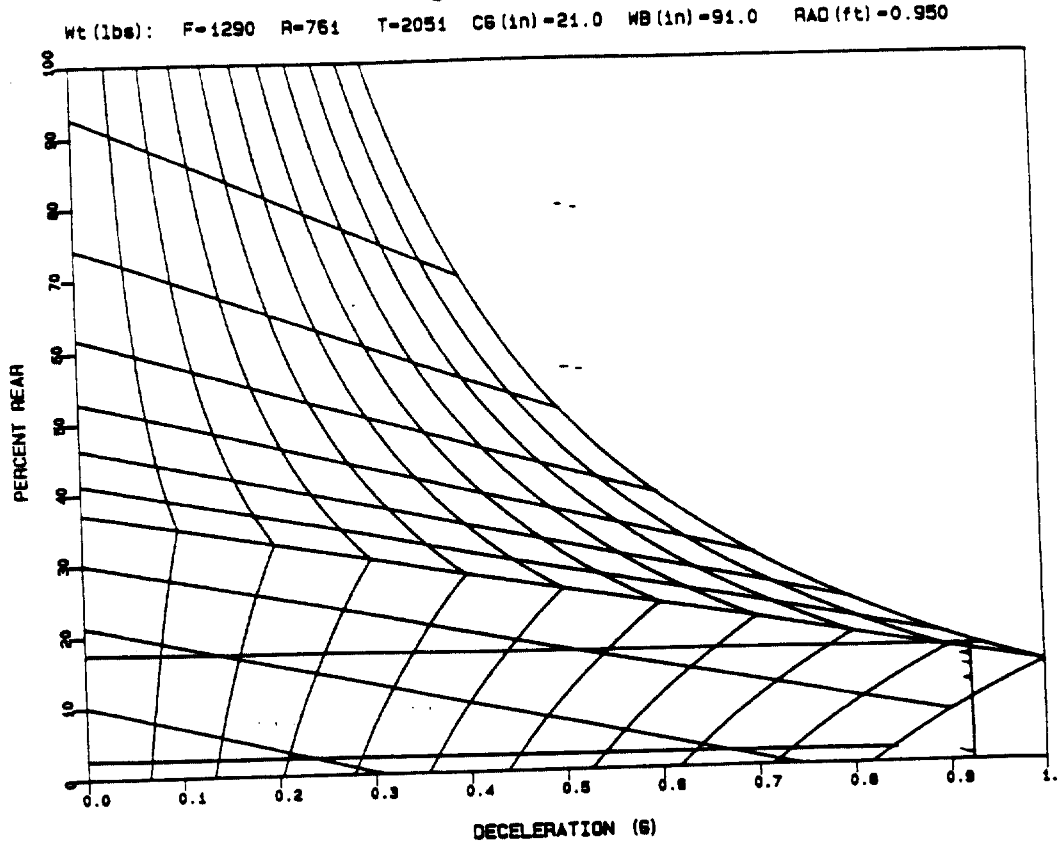


FIGURE 7

Dodge Diplomat Wagon Report 1

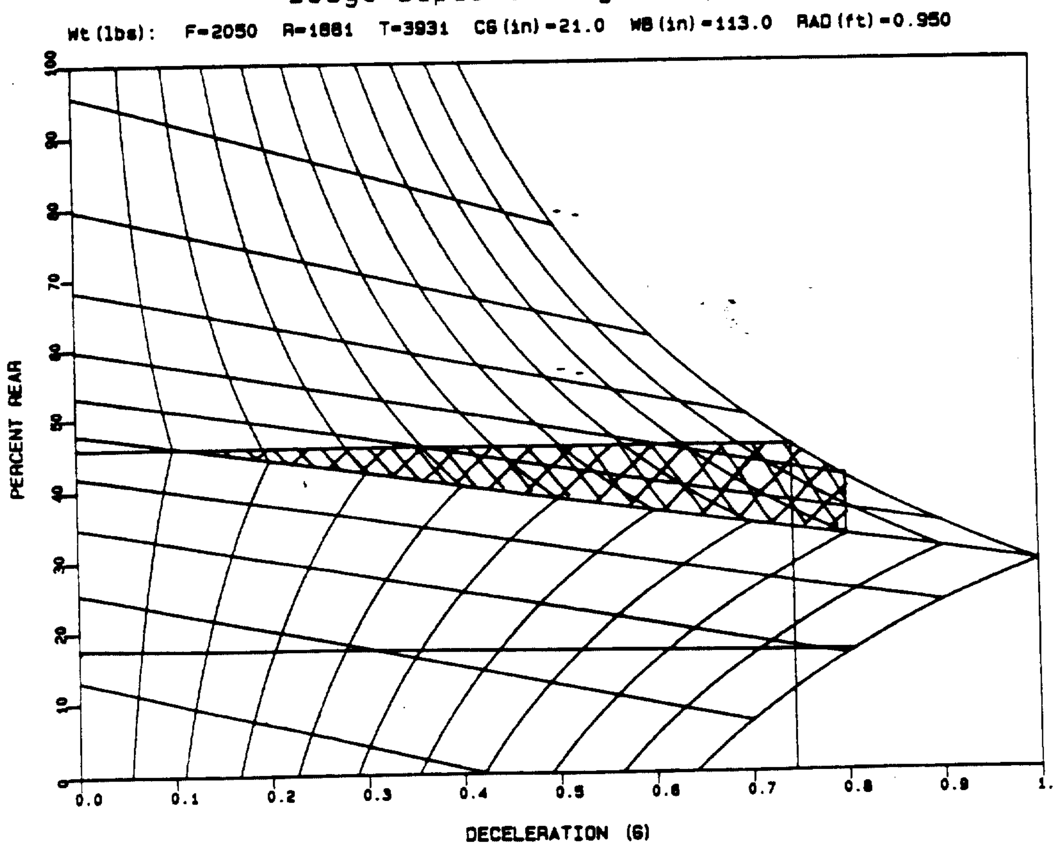


FIGURE 8

Ford EXP Report 1

Wt (lbs): F=1581 R=990 T=2571 CG (in)=21.0 WB (in)=94.0 RAD (ft)=0.950

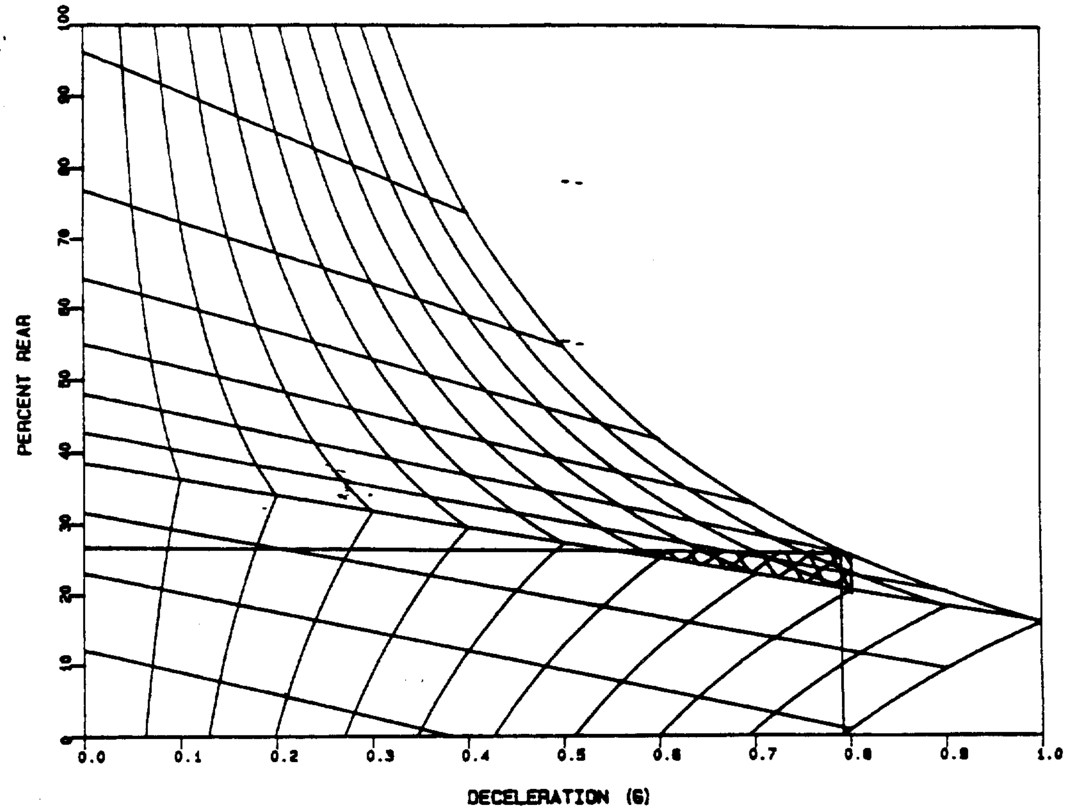


FIGURE 9

Ford Mustang Report 1

Wt (lbs): F=1841 R=1400 T=3241 CG (in)=21.0 WB (in)=100.0 RAD (ft)=0.950

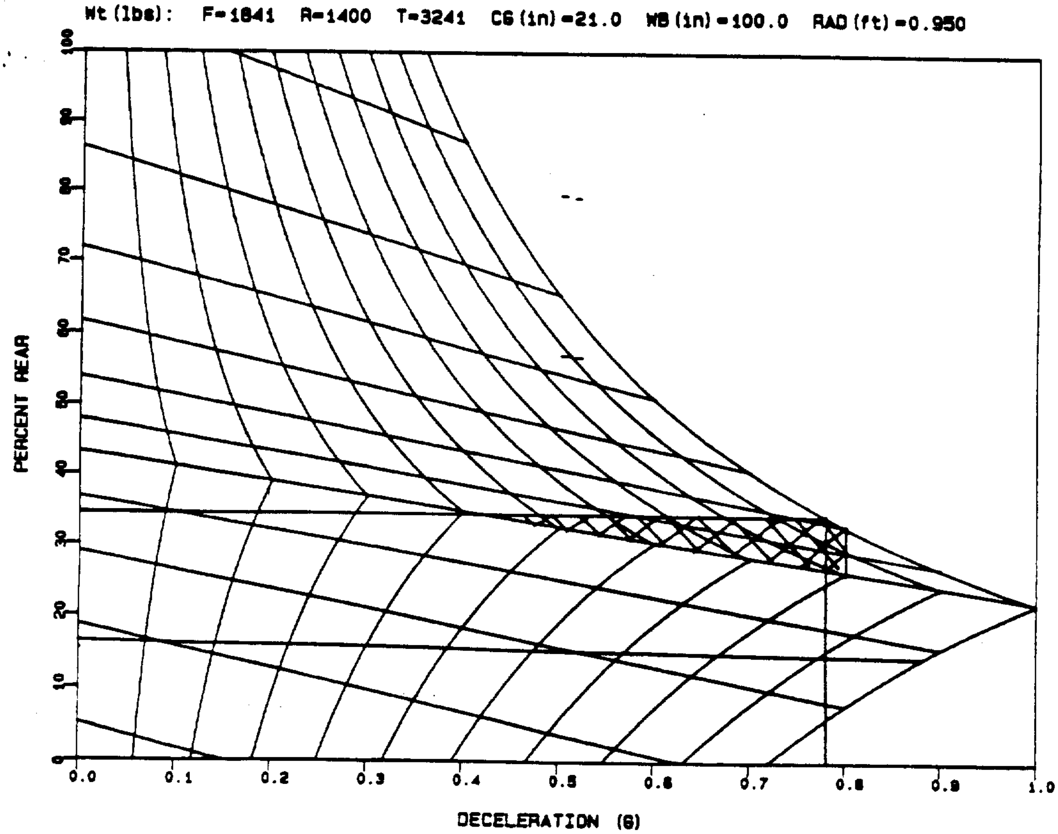


FIGURE 10

Honda Civic Report 1

Wt (lbs): F=1310 R=875 T=2185 CG (in)=21.0 WB (in)=89.0 RAD (ft)=0.950

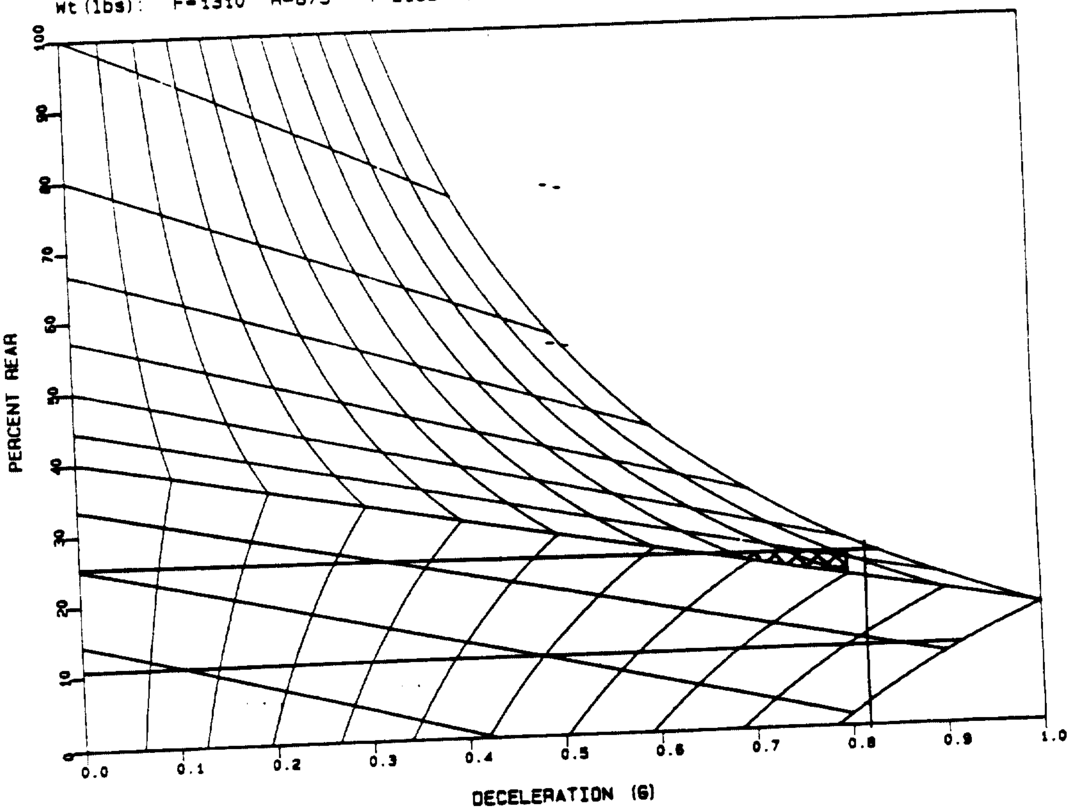


FIGURE 11

Mazda RX-7 Report 1

Wt (lbs): F=1382 R=1305 T=2687 CG (in)=21.0 WB (in)=95.0 RAD (ft)=0.950

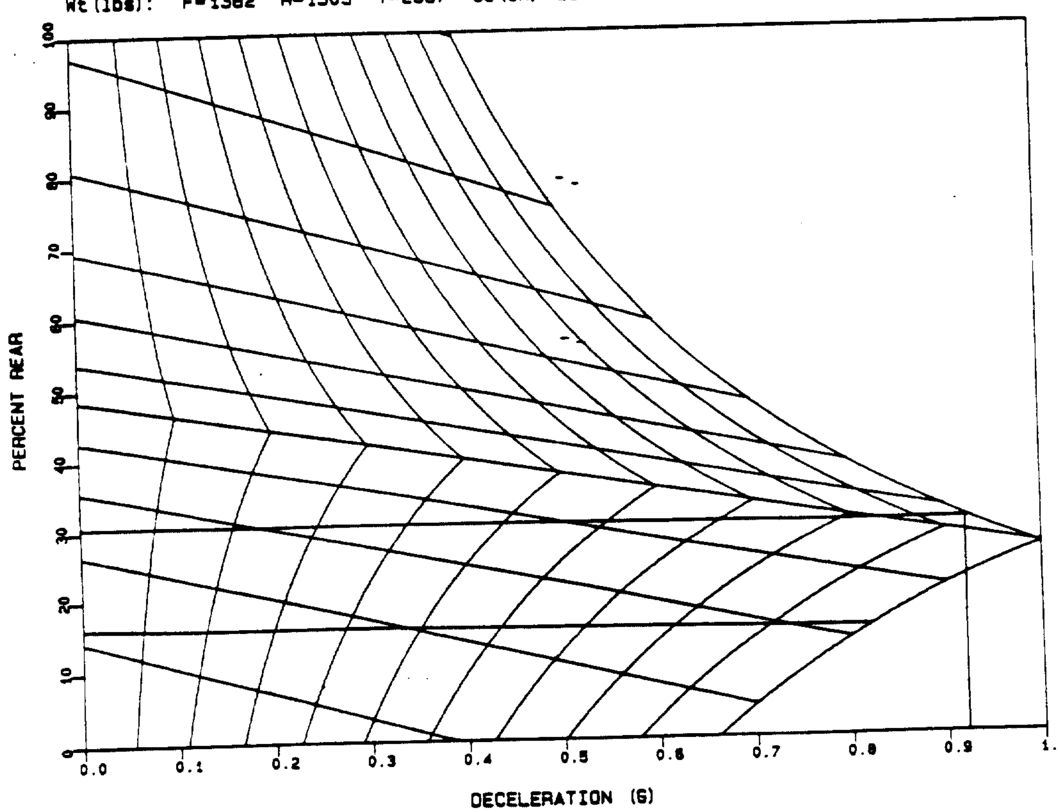


FIGURE 12

Mercury Marquis Wagon Report 1

Wt(lbs): F=2161 R=2059 T=4220 CG(in)=21.0 WB(in)=114.0 RAD(ft)=0.950

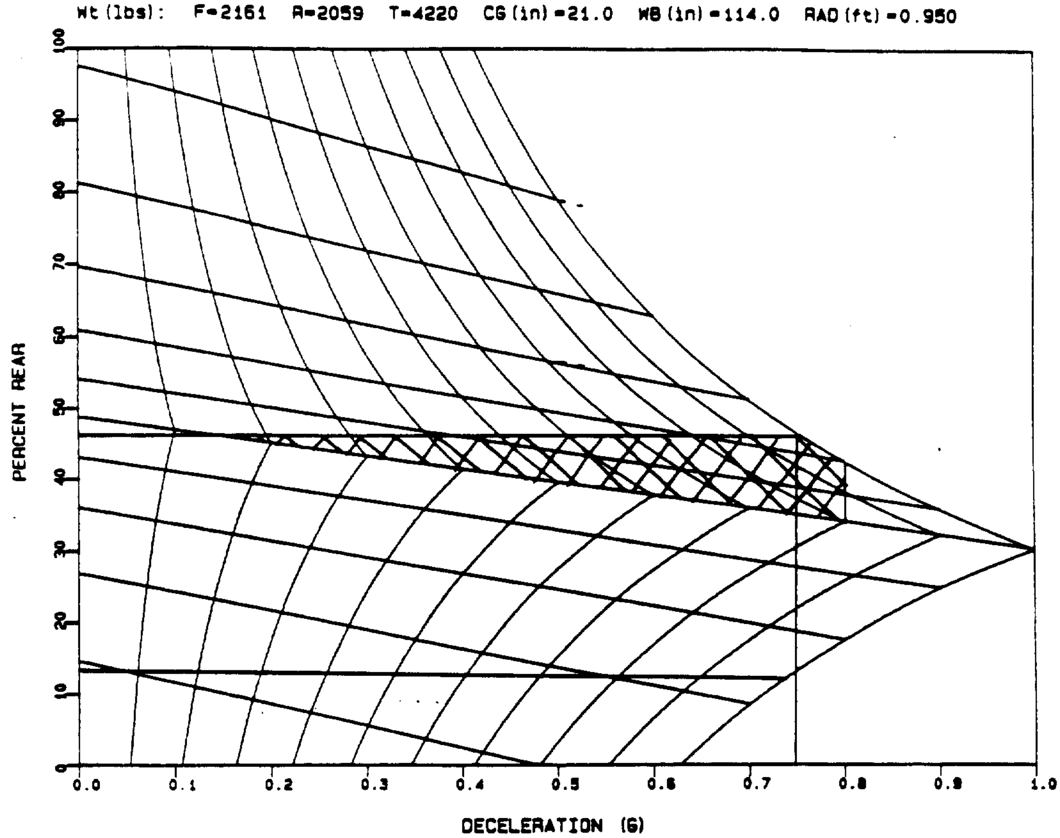


FIGURE 13

Nissan Sentra Report 1

Wt(lbs): F=1321 R=939 T=2260 CG(in)=21.0 WB(in)=95.0 RAD(ft)=0.950

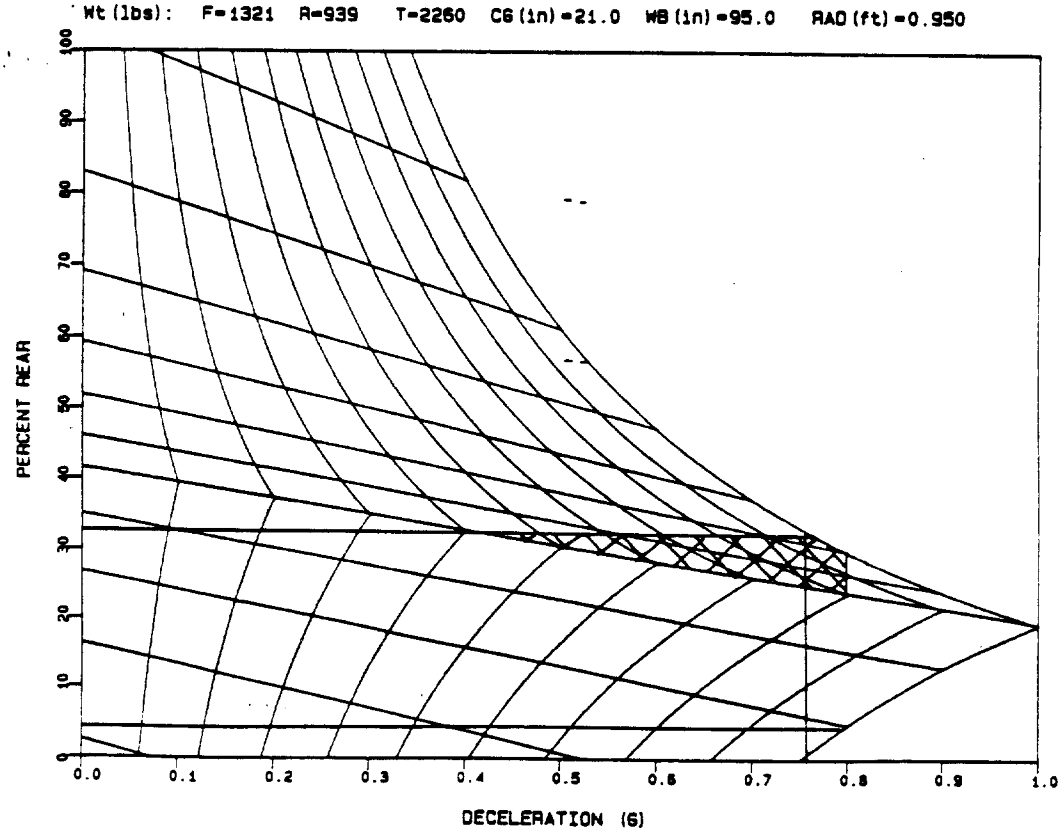


FIGURE 14

Oldsmobile Cruiser Wagon Report 1

Wt (lbs): F=2401 R=2330 T=4731 CG (in)=21.0 WB (in)=116.0 RAD (ft)=0.950

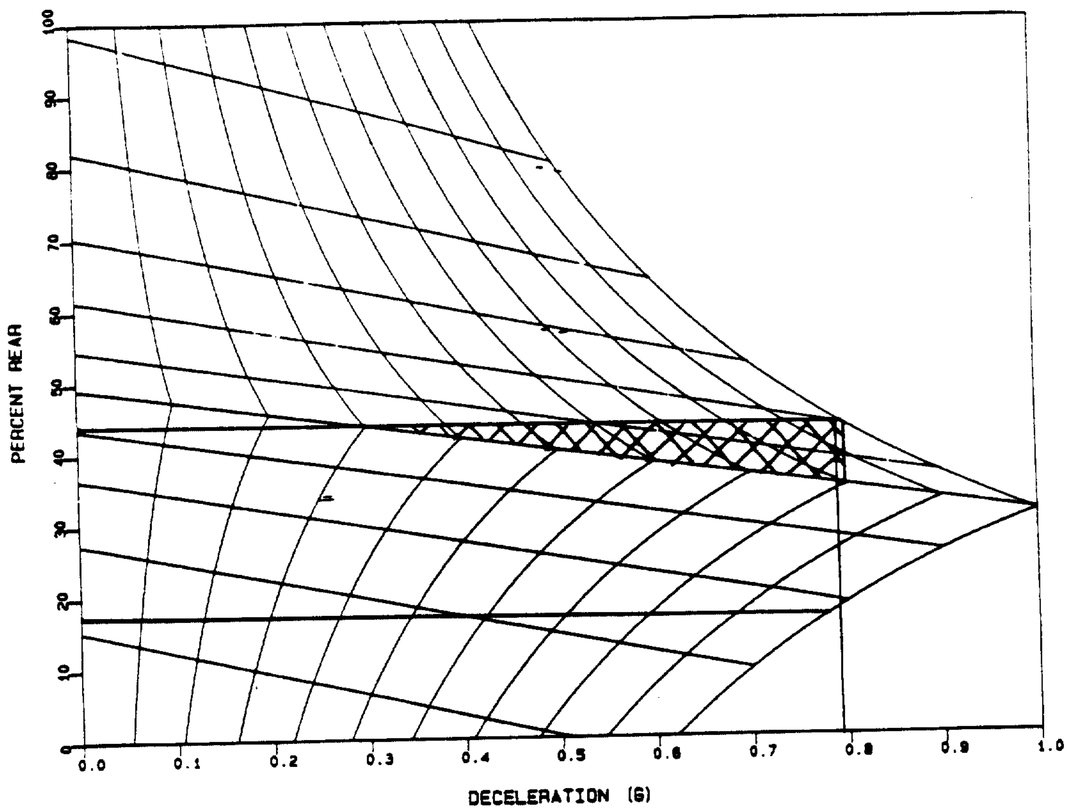


FIGURE 15

Oldsmobile Toronado Report 1

Wt (lbs): F=2815 R=1715 T=4530 CG (in)=21.0 WB (in)=114.0 RAD (ft)=0.950

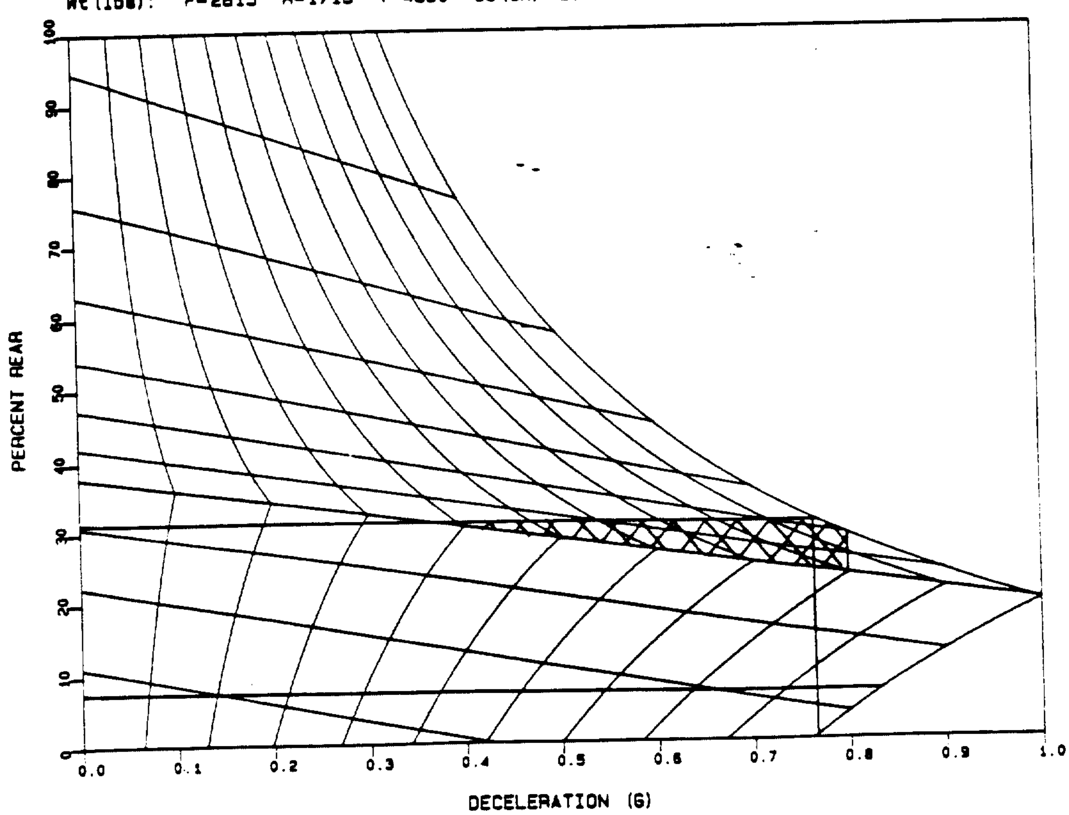


FIGURE 16

Plymouth Gran Fury Report 1

Wt (lbs): F=2150 R=1660 T=3810 CG (in)=21.0 WB (in)=113.0 RAD (ft)=0.950

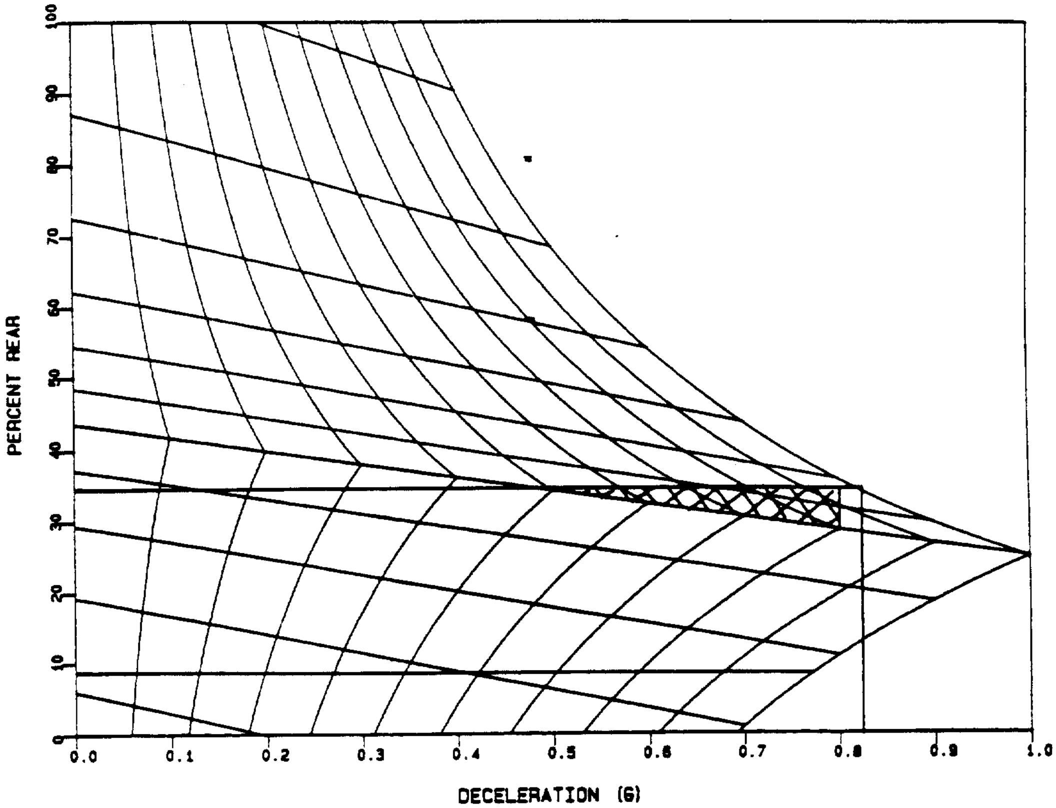


FIGURE 17

Plymouth Horizon Report 1

Wt (lbs): F=1720 R=970 T=2690 CG (in)=21.0 WB (in)=99.0 RAD (ft)=0.950

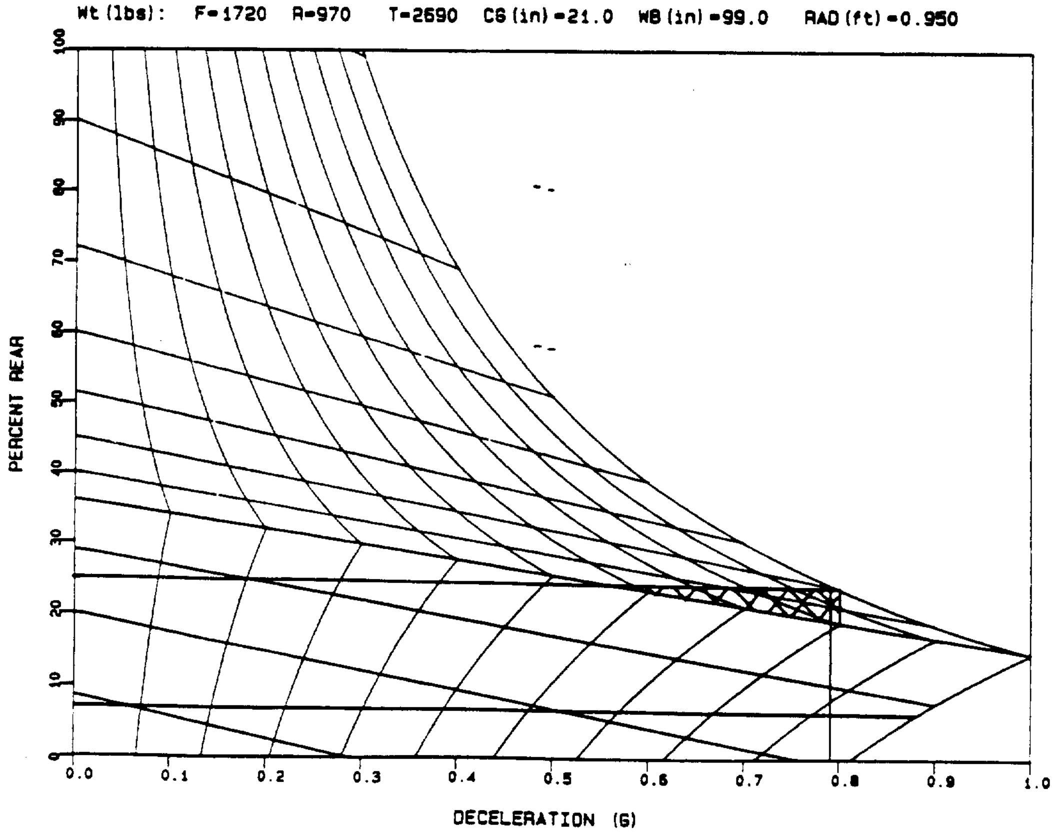


FIGURE 18

Renault 18i Report 1

Wt (lbs): F=1700 R=1030 T=2730 CG (in)=21.0 WB (in)=97.0 RAD (ft)=0.950

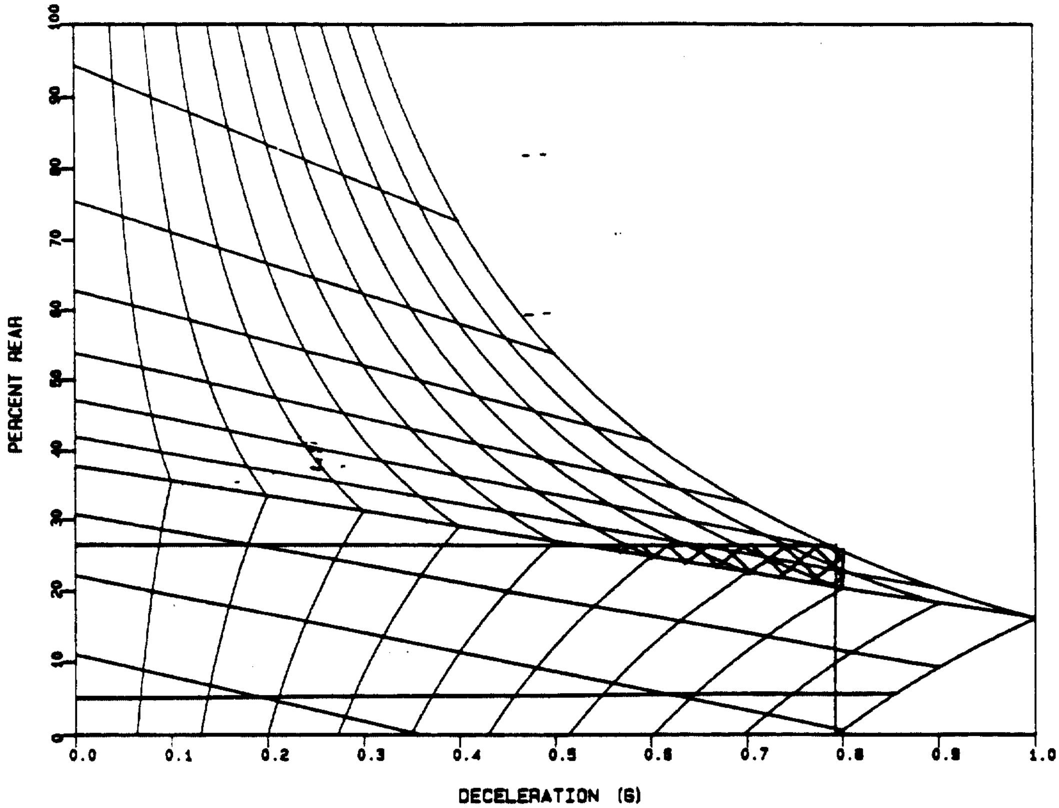


FIGURE 19

Toyota Cressida Report 1

Wt (lbs): F=1750 R=1479 T=3229 CG (in)=21.0 WB (in)=104.0 RAD (ft)=0.950

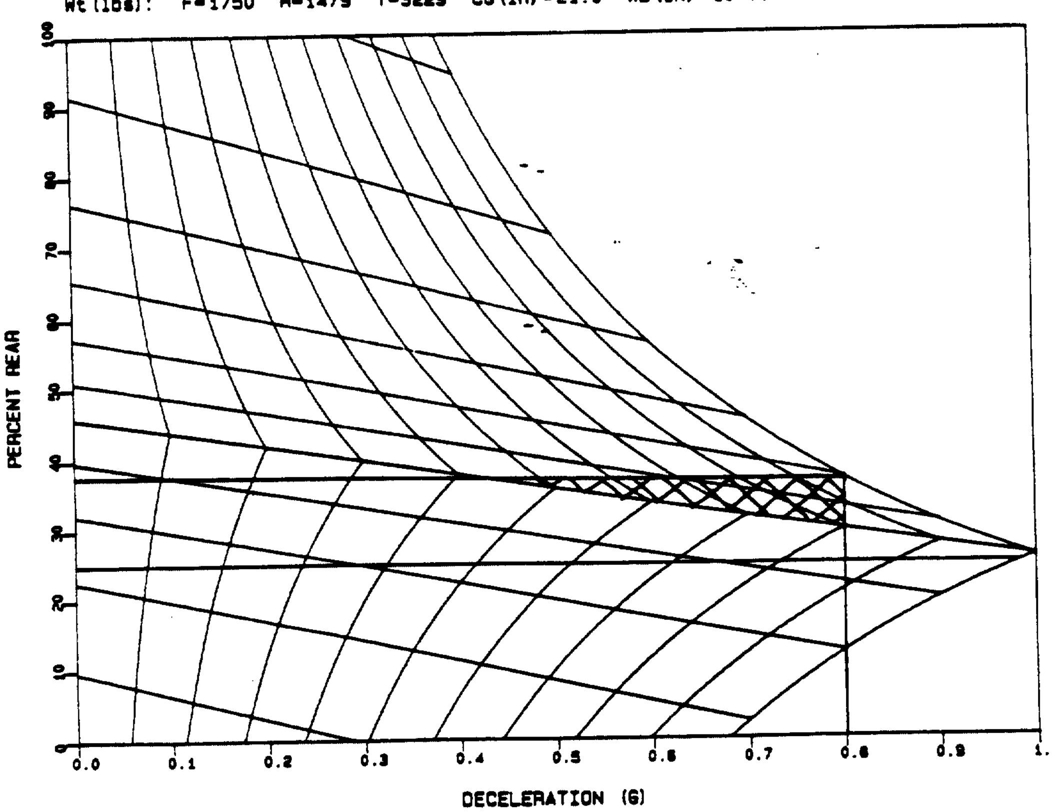


FIGURE 20

Toyota Starlet Report 1

Wt (lbs): F=1124 R=1001 T=2125 CG (in)=21.0 WB (in)=91.0 RAD (ft)=0.950

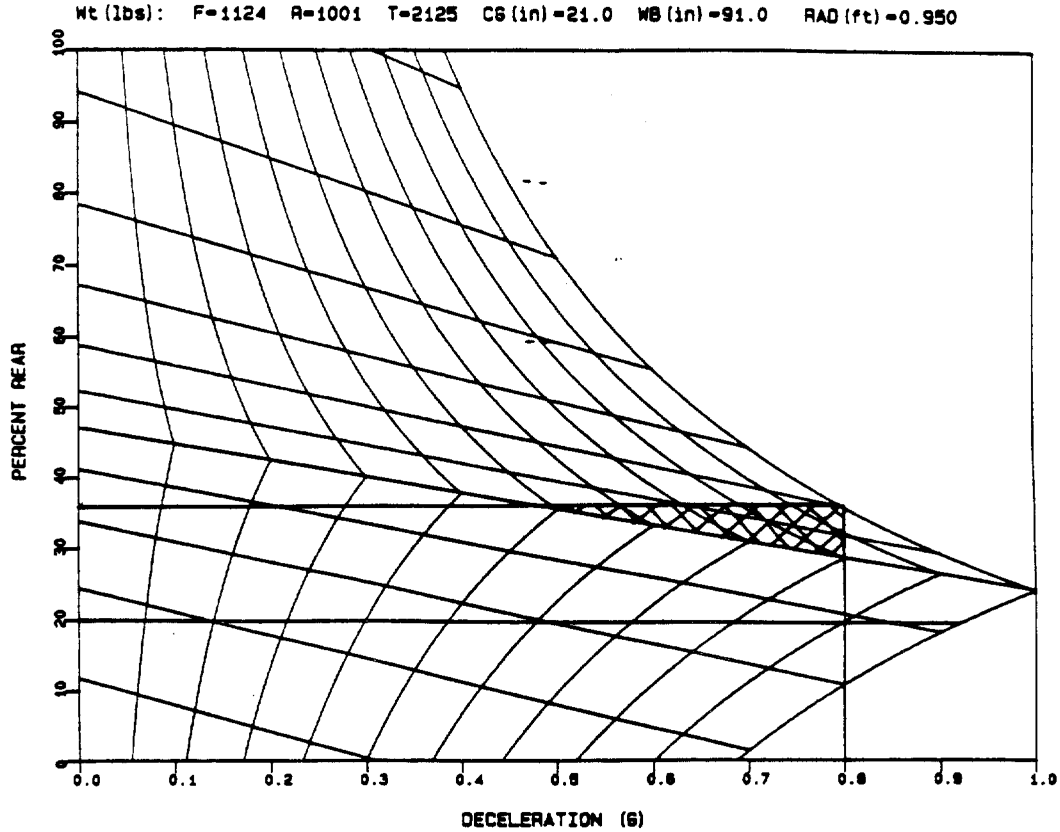


FIGURE 21

Volkswagen Rabbit Report 1

Wt (lbs): F=1411 R=911 T=2322 CG (in)=21.0 WB (in)=94.0 RAD (ft)=0.950

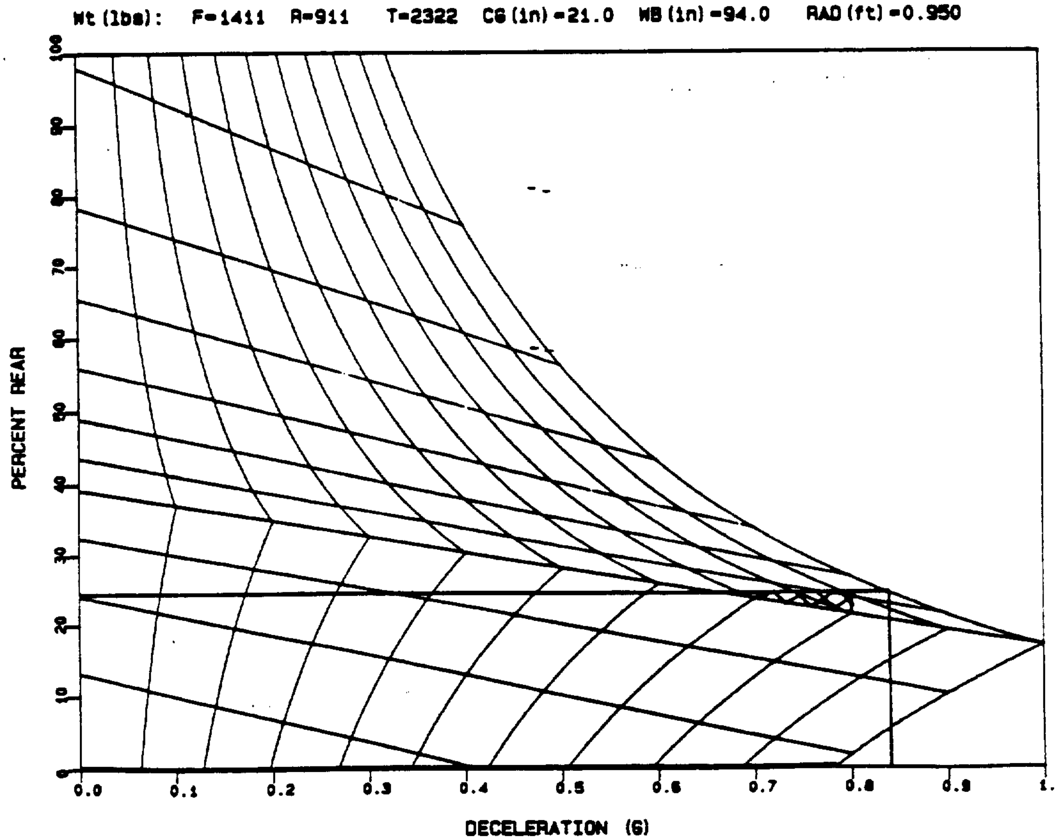


FIGURE 22

Volvo 244 Report 1

Wt (lbs): F=1711 R=1680 T=3391 CG (in)=21.0 WB (in)=104.0 RAD (ft)=0.950

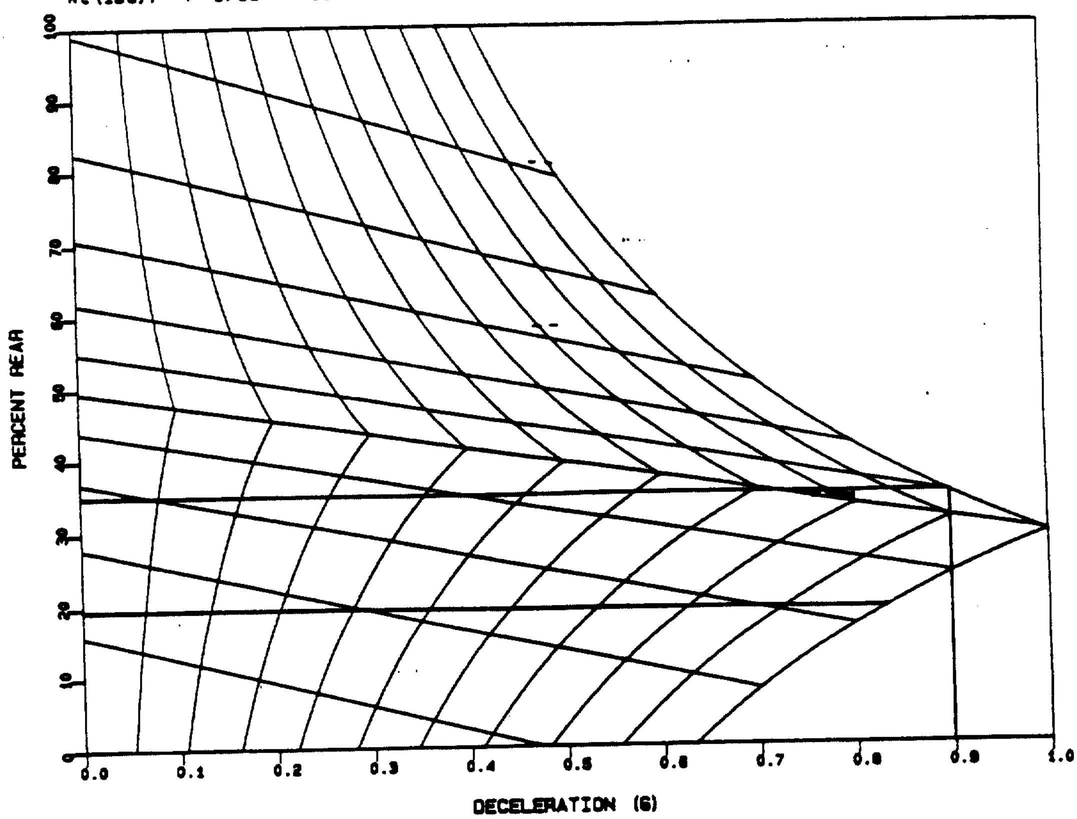


FIGURE 23

Chevrolet Citation Report 1 (#1 With Burnish)

Wt (lbs): F=1991 R=1135 T=3126 CG (in)=21.0 WB (in)=105.0 RAD (ft)=0.950

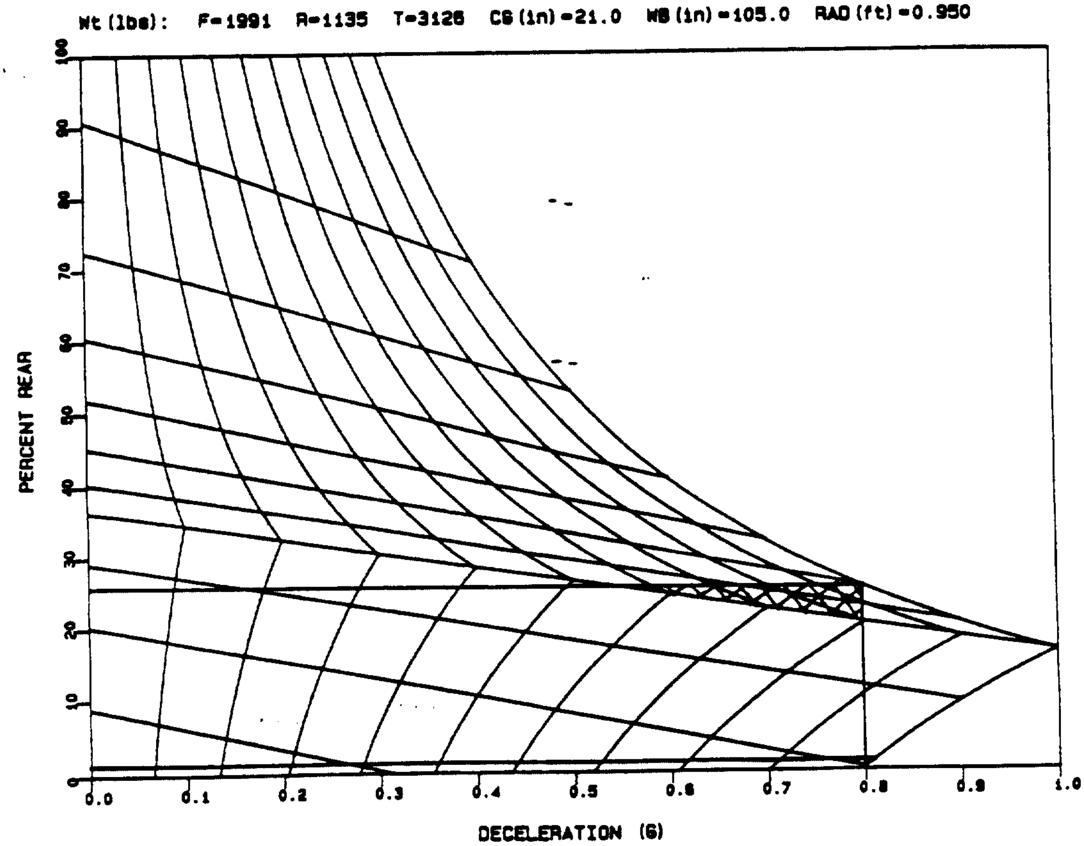


FIGURE 24

Ford Mustang Report 1 (With Burnish)

Wt (lbs): F=1841 R=1400 T=3241 CG (in)=21.0 WB (in)=100.0 RAD (ft)=0.950

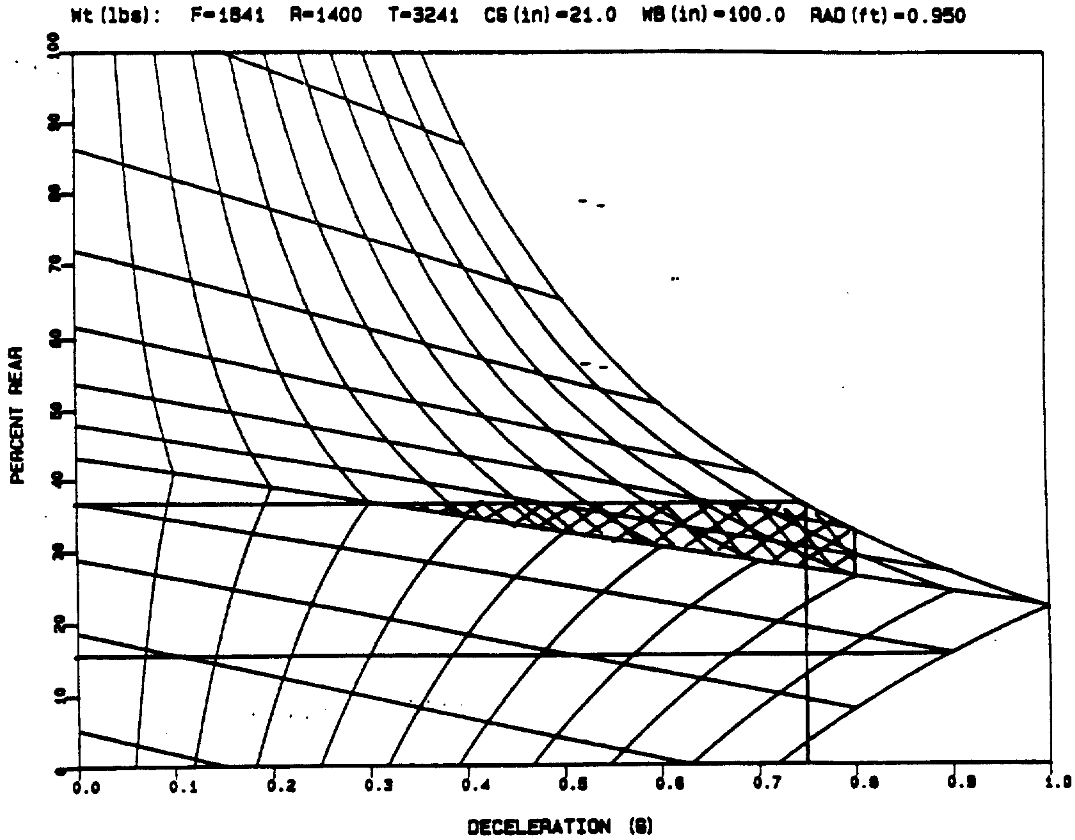


FIGURE 25

Nissan Sentra Report 1 (With Burnish)

Wt (lbs): F=1321 R=939 T=2260 CG (in)=21.0 WB (in)=95.0 RAD (ft)=0.950

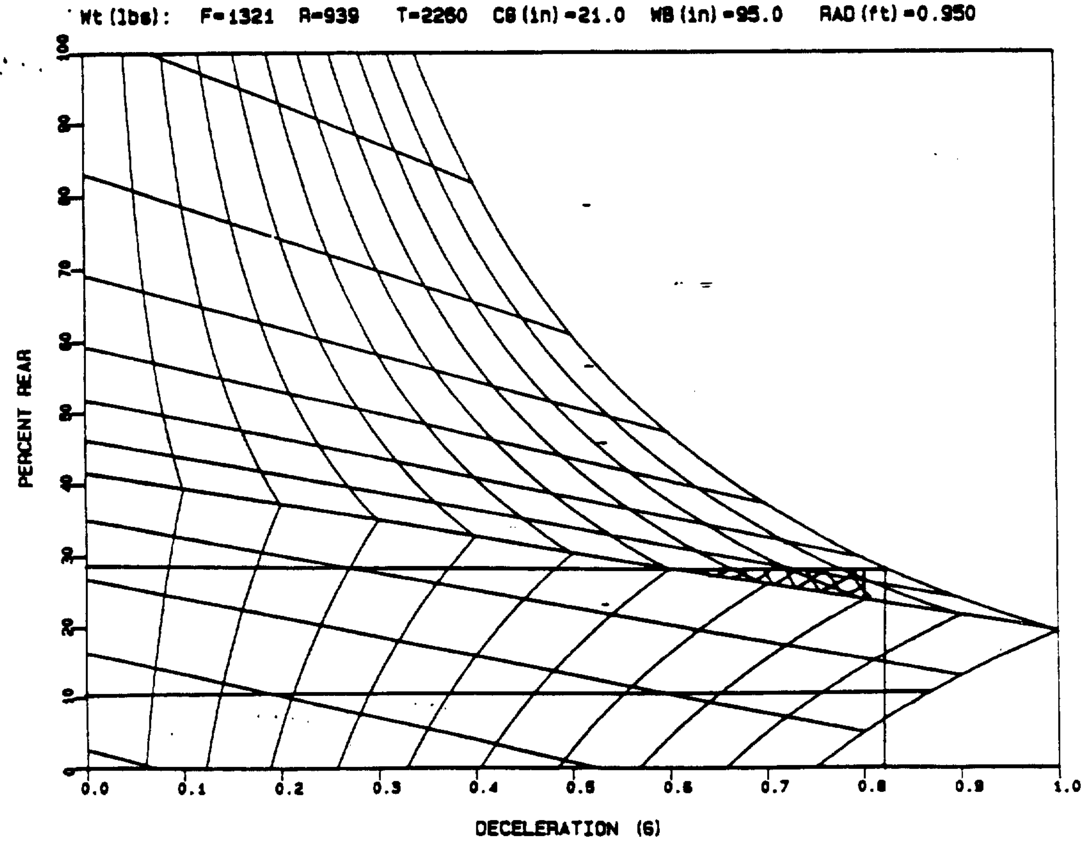


FIGURE 26

Oldsmobile Cruiser Wagon Report 1 (With Burnish)

Wt (lbs): F=2401 R=2330 T=4731 CG (in)=21.0 WB (in)=116.0 RAD (ft)=0.950

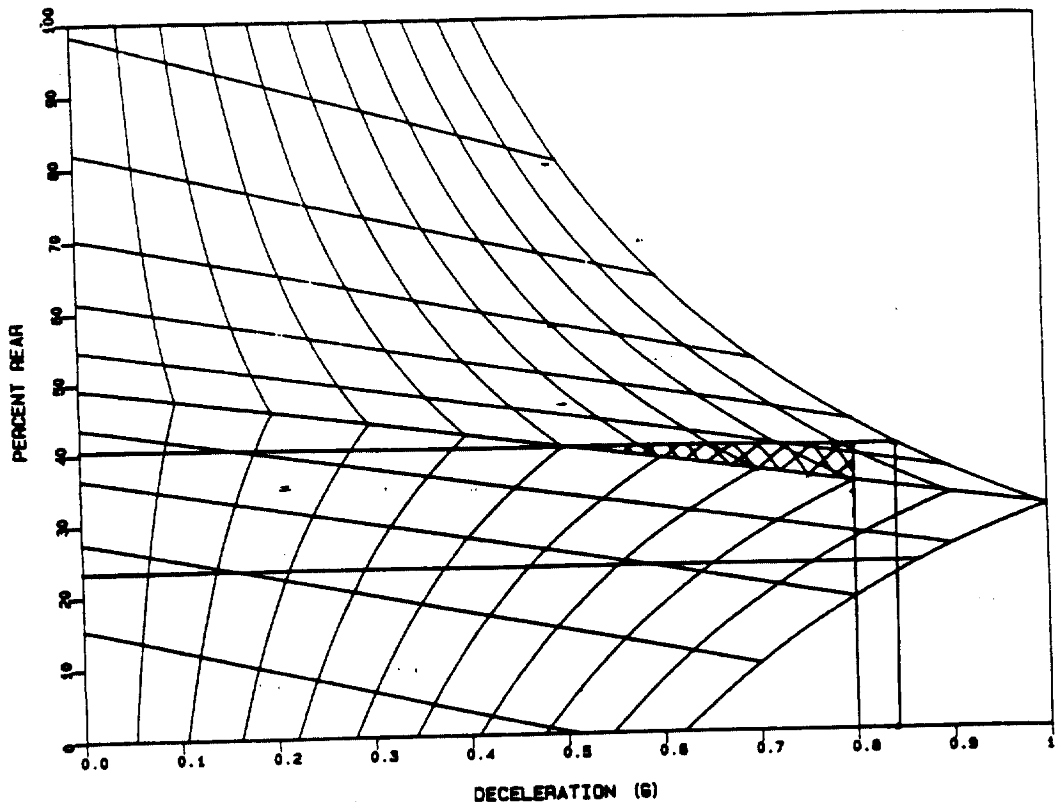


FIGURE 27

Ford EXP/Escort Report 2

Wt (lbs): F=1570 R=915 T=2485 CG (in)=21.0 WB (in)=94.0 RAD (ft)=0.950

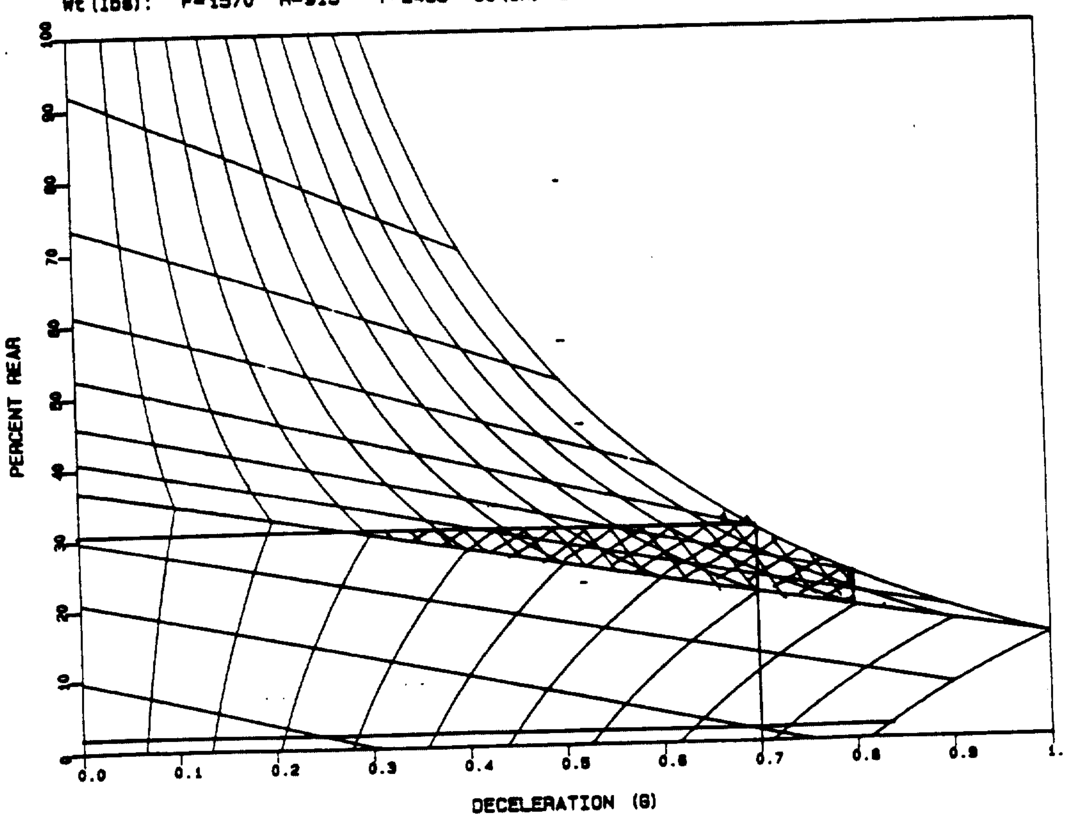


FIGURE 28

Ford Granada/LTD Report 2

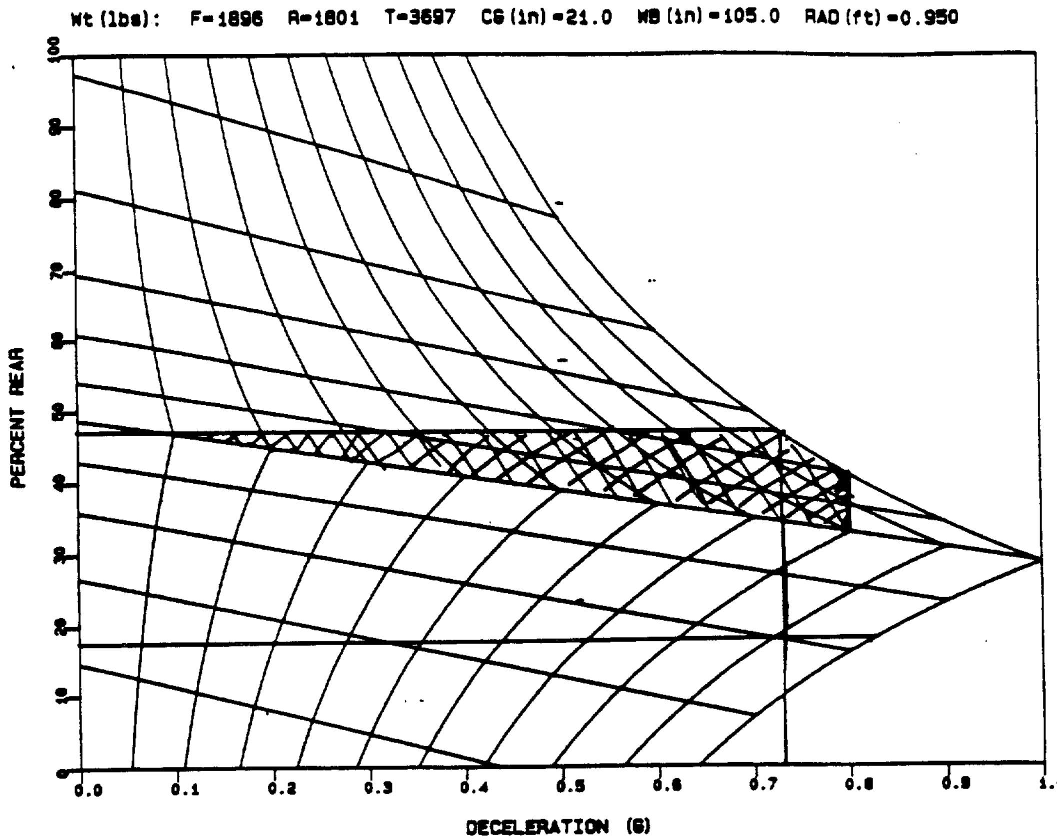


FIGURE 29

Nissan Sentra Report 2

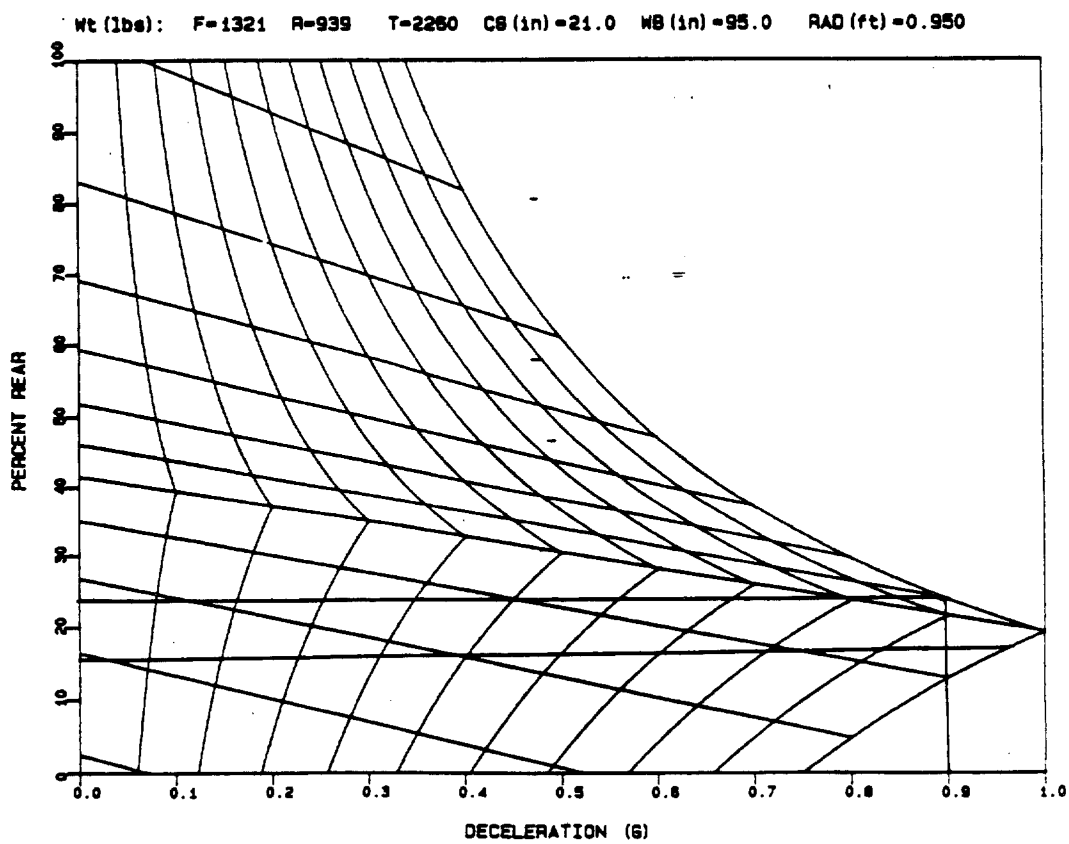


FIGURE 30

Plymouth Horizon Report 2

Wt (lbs): F=1720 R=970 T=2690 CG (in)=21.0 WB (in)=99.0 RAD (ft)=0.950

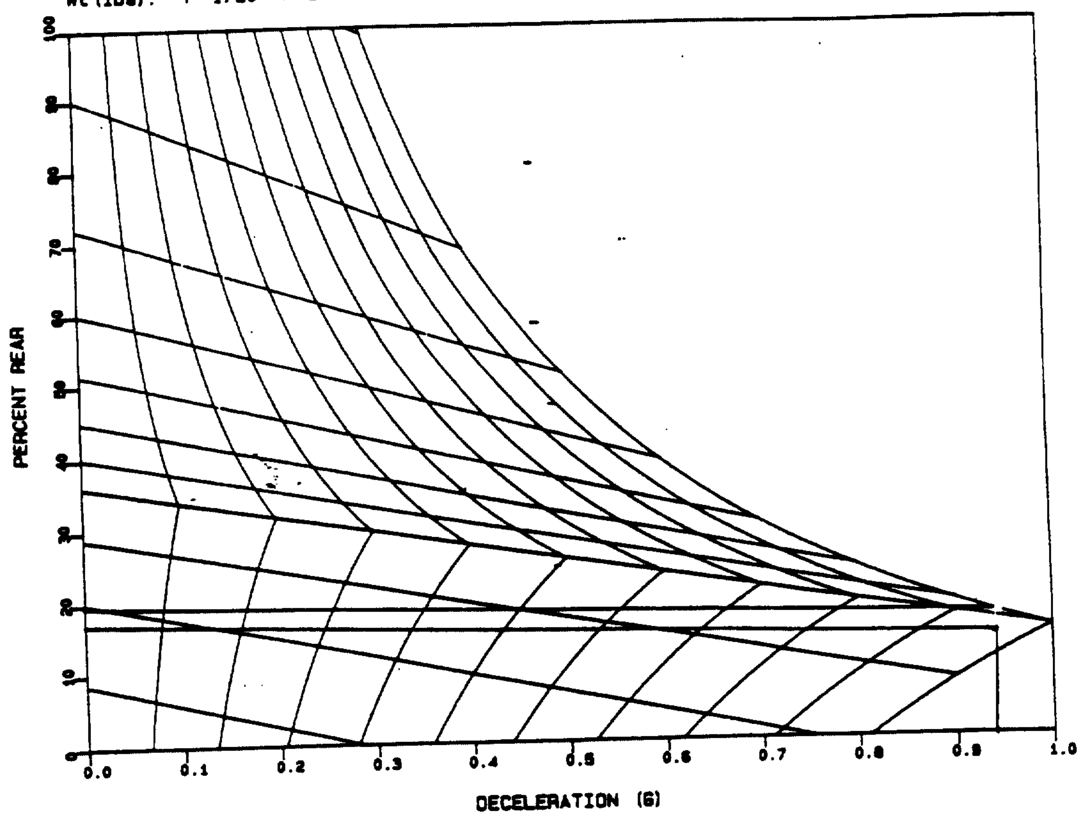


FIGURE 31

BMW 735i Report 3

Wt (lbs): F=2030 R=1825 T=3855 CG (in)=21.0 WB (in)=110.0 RAD (ft)=0.950

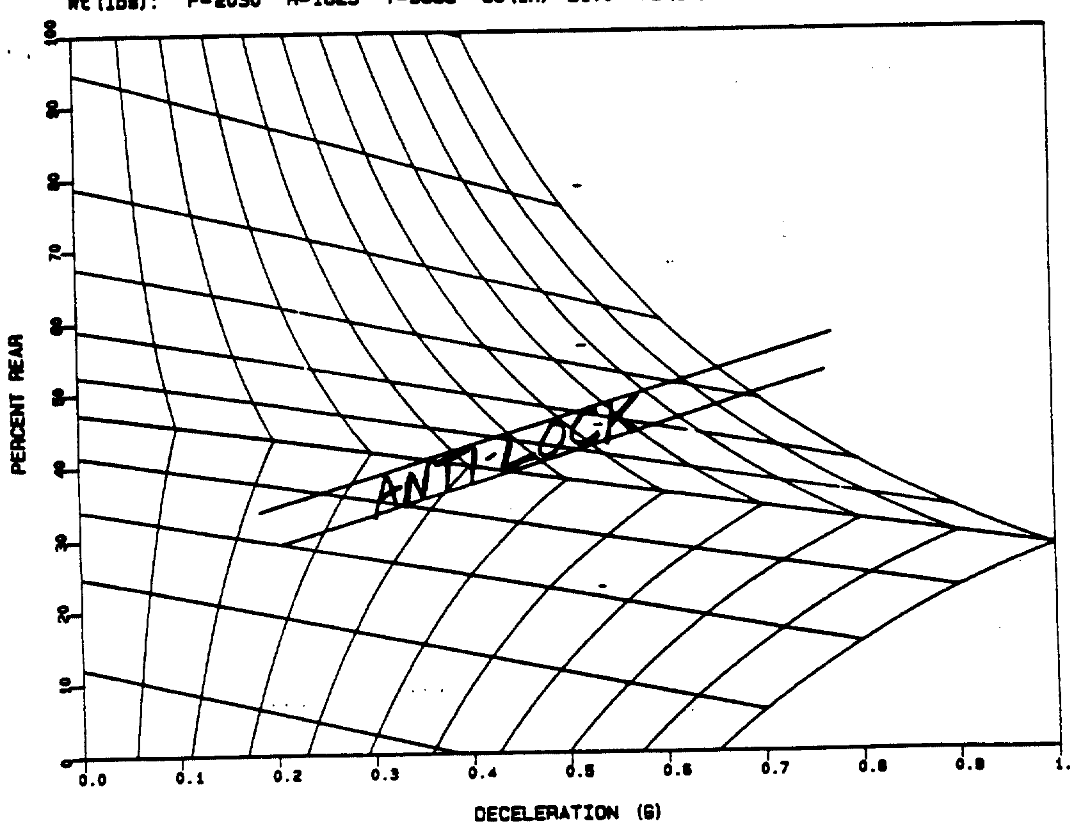


FIGURE 32

Chevrolet Caprice Classic Report 3

Wt (lbs): F=2079 R=1799 T=3878 CG (in)=21.0 WB (in)=116.0 RAD (ft)=0.950

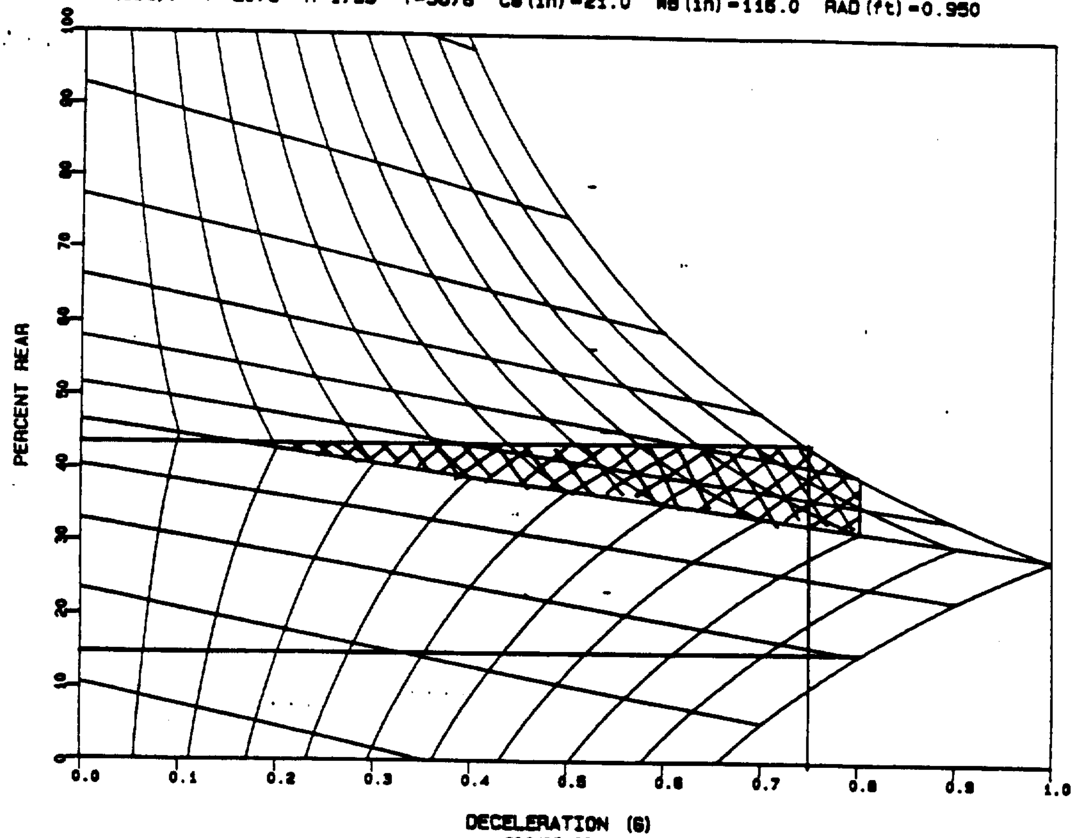


FIGURE 33

Chevrolet Cavalier Report 3

Wt (lbs): F=1971 R=1021 T=2992 CG (in)=21.0 WB (in)=100.0 RAD (ft)=0.950

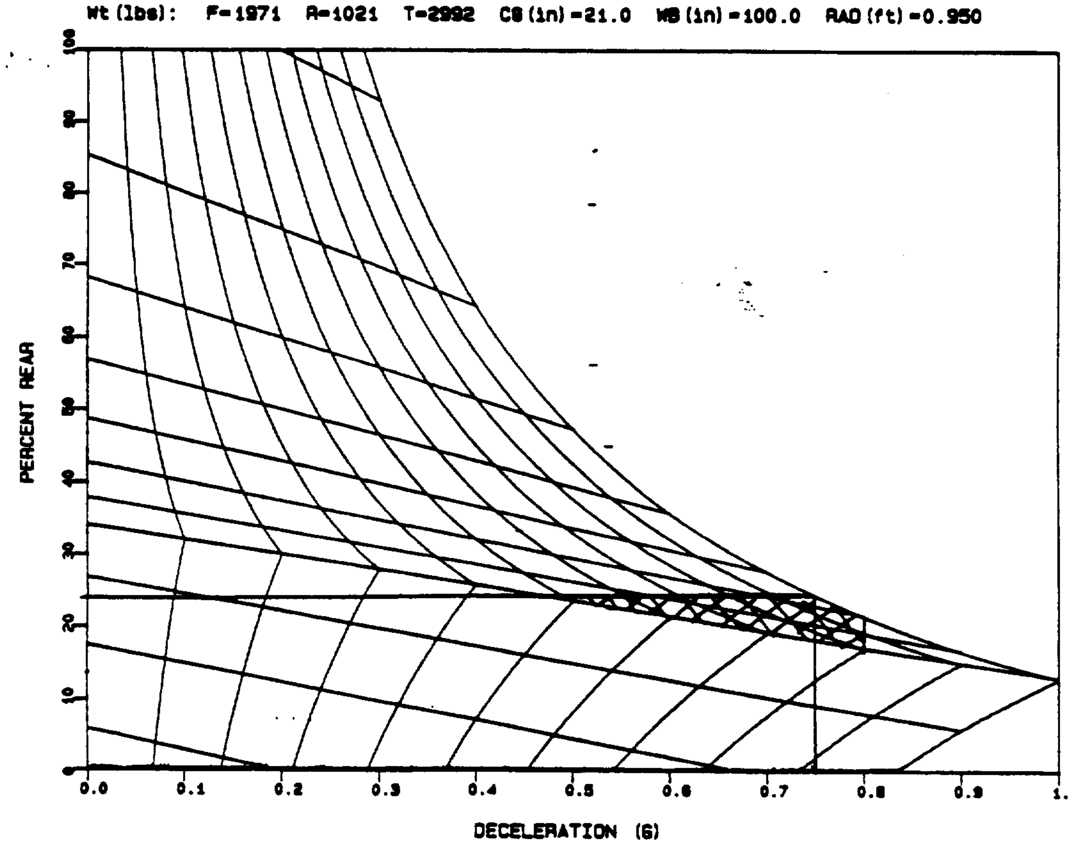


FIGURE 34

Dodge 600 Report 3

Wt (lbs): F=1779 R=1151 T=2930 CG (in)=21.0 WB (in)=103.0 RAD (ft)=0.950

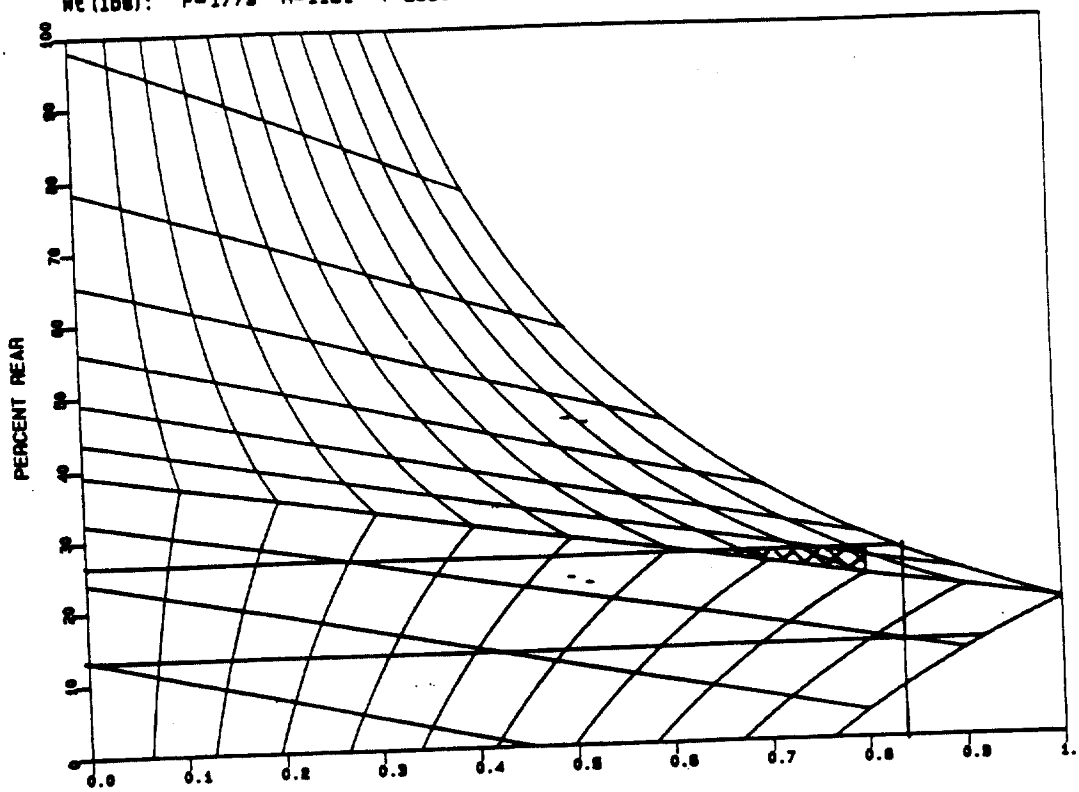


FIGURE 35

Ford Granada Report 3

Wt (lbs): F=1825 R=1746 T=3571 CG (in)=21.0 WB (in)=106.0 RAD (ft)=0.950

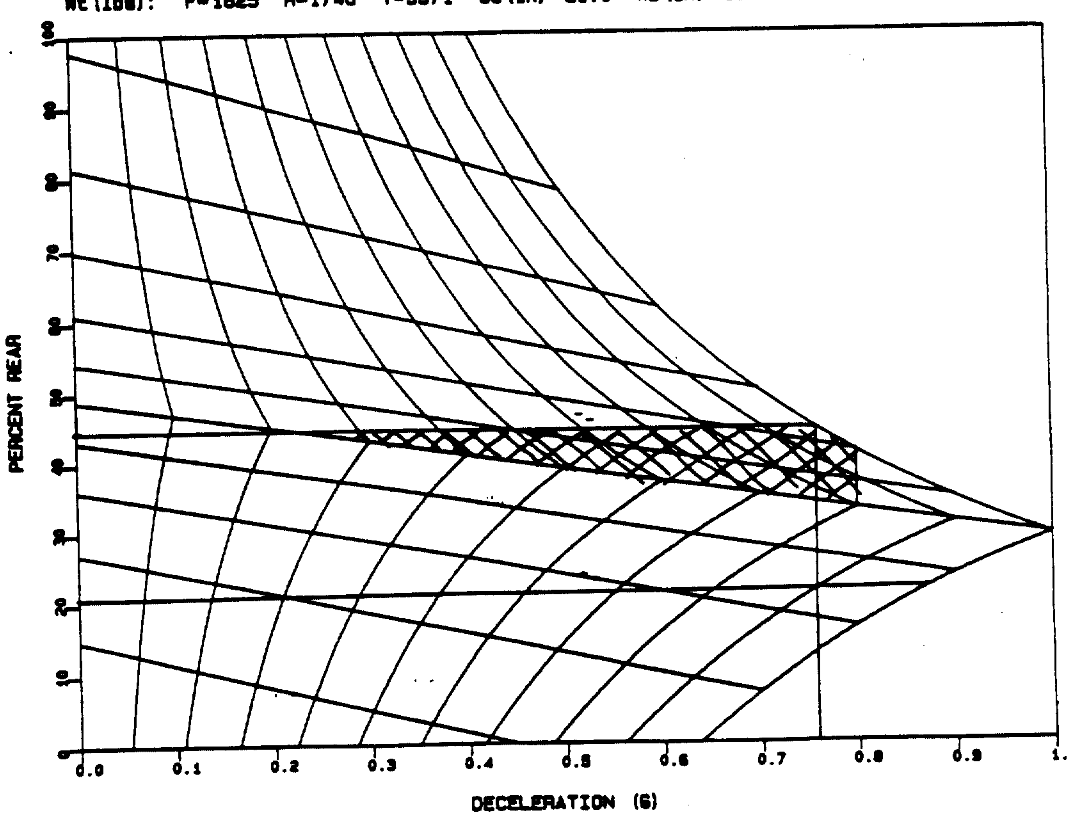


FIGURE 36

Ford Tempo Report 3

Wt (lbs): F=1779 R=1069 T=2848 CG (in)=21.0 WB (in)=100.0 RAD (ft)=0.950

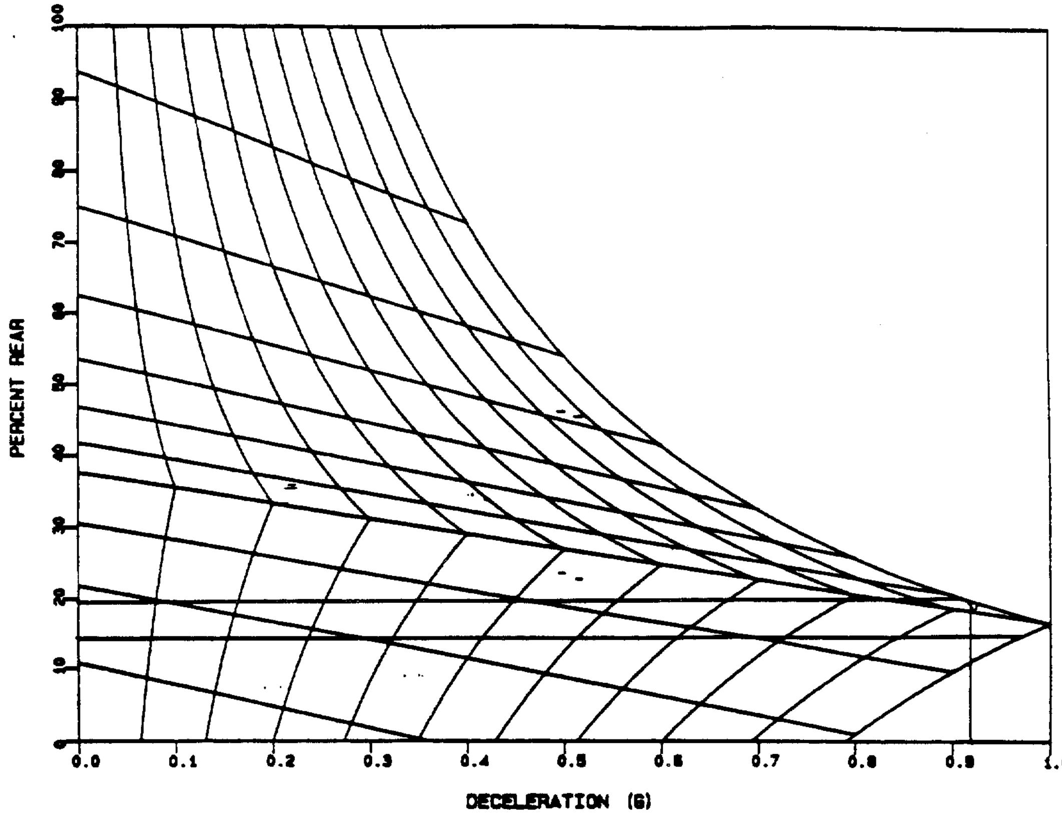


FIGURE 37

Ford Thunderbird Report 3

Wt (lbs): F=1874 R=1629 T=3503 CG (in)=21.0 WB (in)=104.0 RAD (ft)=0.950

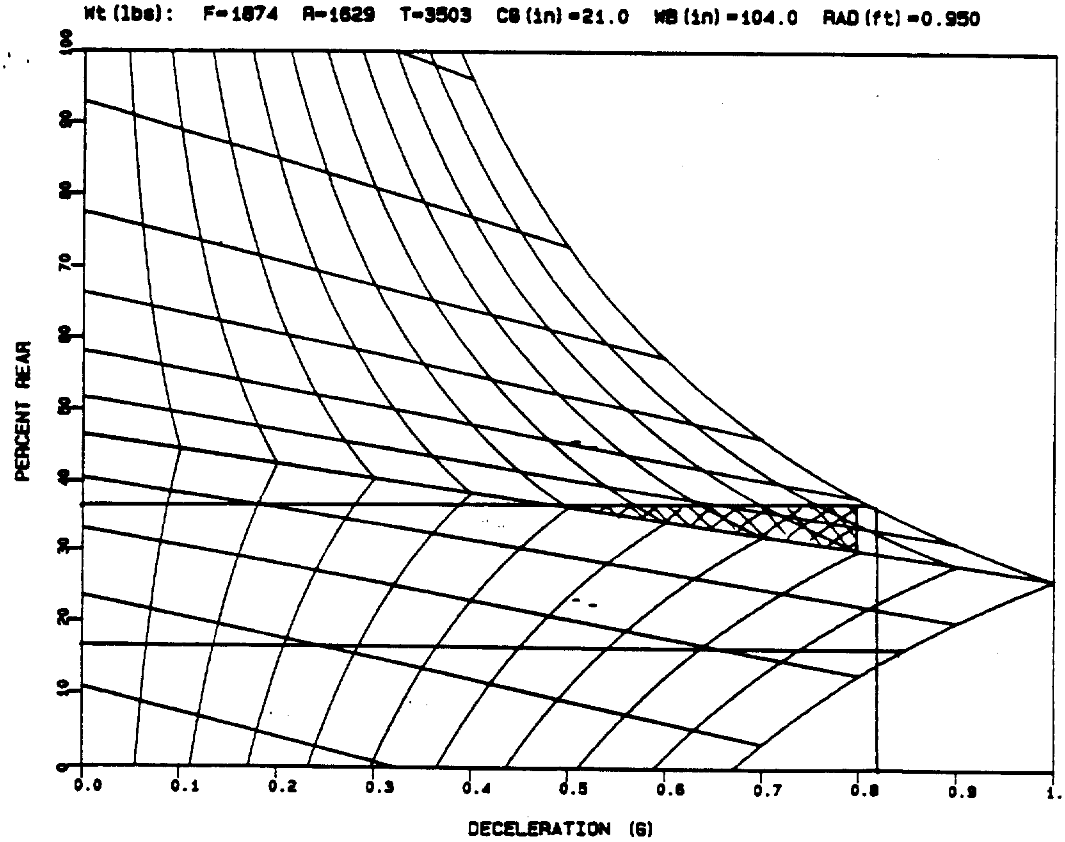


FIGURE 38

Honda Prelude Report 3

Wt (lbs): F=1545 R=1010 T=2555 CG (in)=21.0 WB (in)=98.0 RAD (ft)=0.950

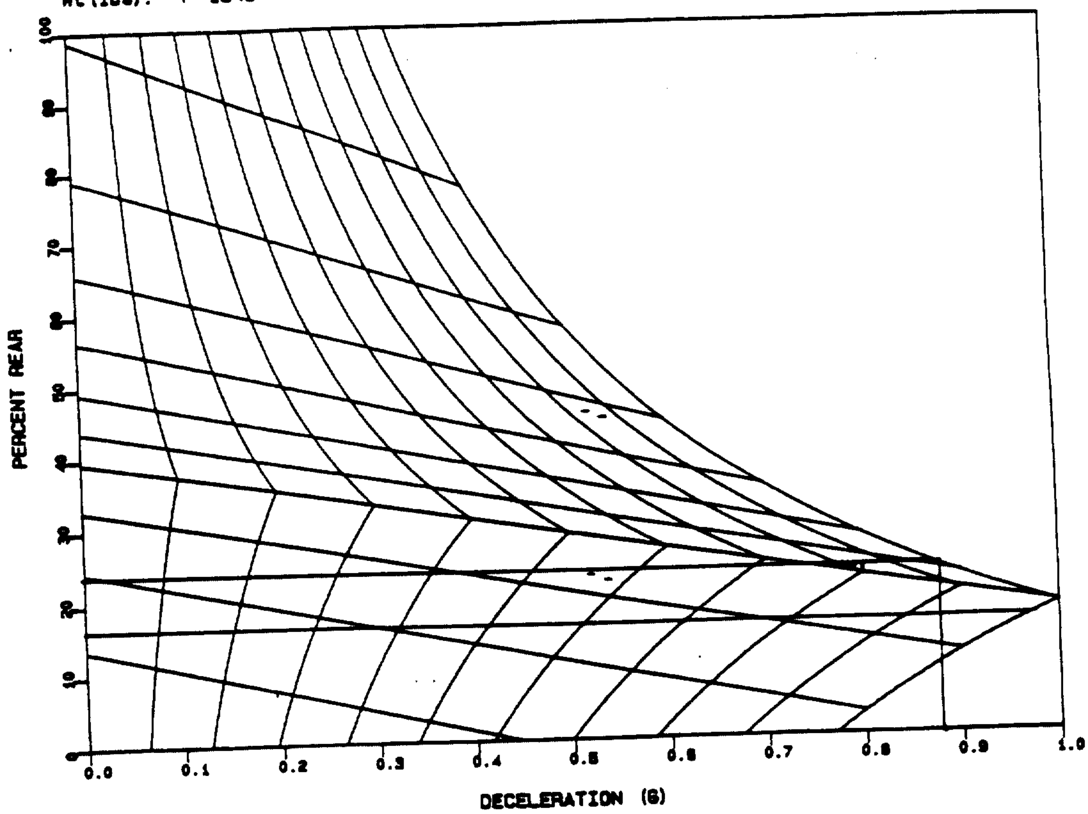


FIGURE 39

Isuzu Impulse Report 3

Wt (lbs): F=1715 R=1360 T=3075 CG (in)=21.0 WB (in)=95.0 RAD (ft)=0.950

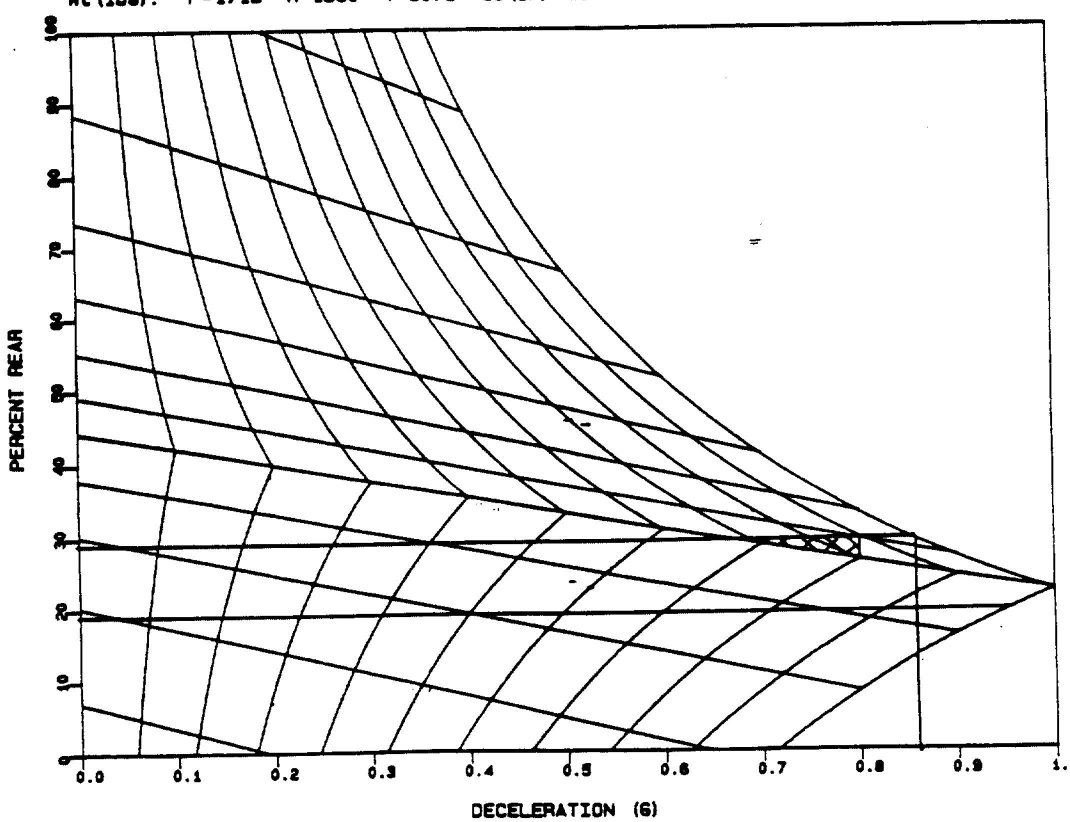


FIGURE 40

Mazda-Toyo-Kogyo 626D Report 3

Wt (lbs): F=1601 R=1080 T=2681 CG (in)=21.0 WB (in)=105.0 RAD (ft)=0.950

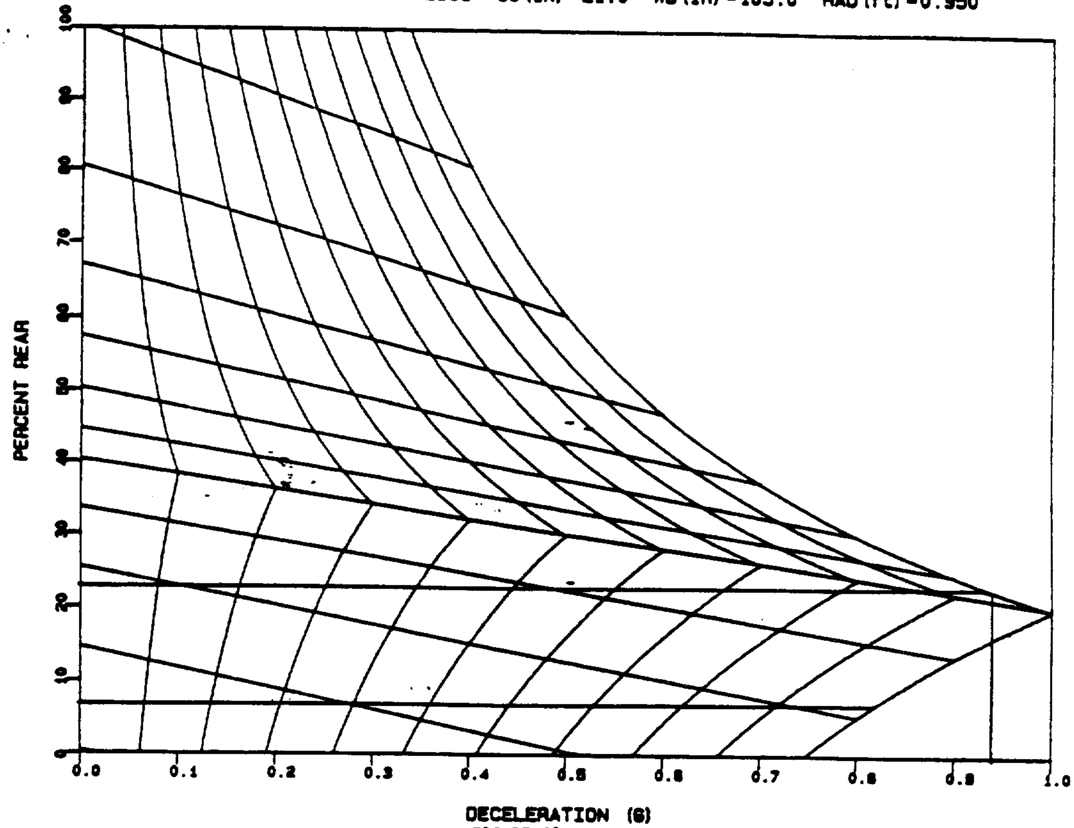


FIGURE 41

Mitsubishi Starion Report 3

Wt (lbs): F=1795 R=1601 T=3396 CG (in)=21.0 WB (in)=96.0 RAD (ft)=0.950

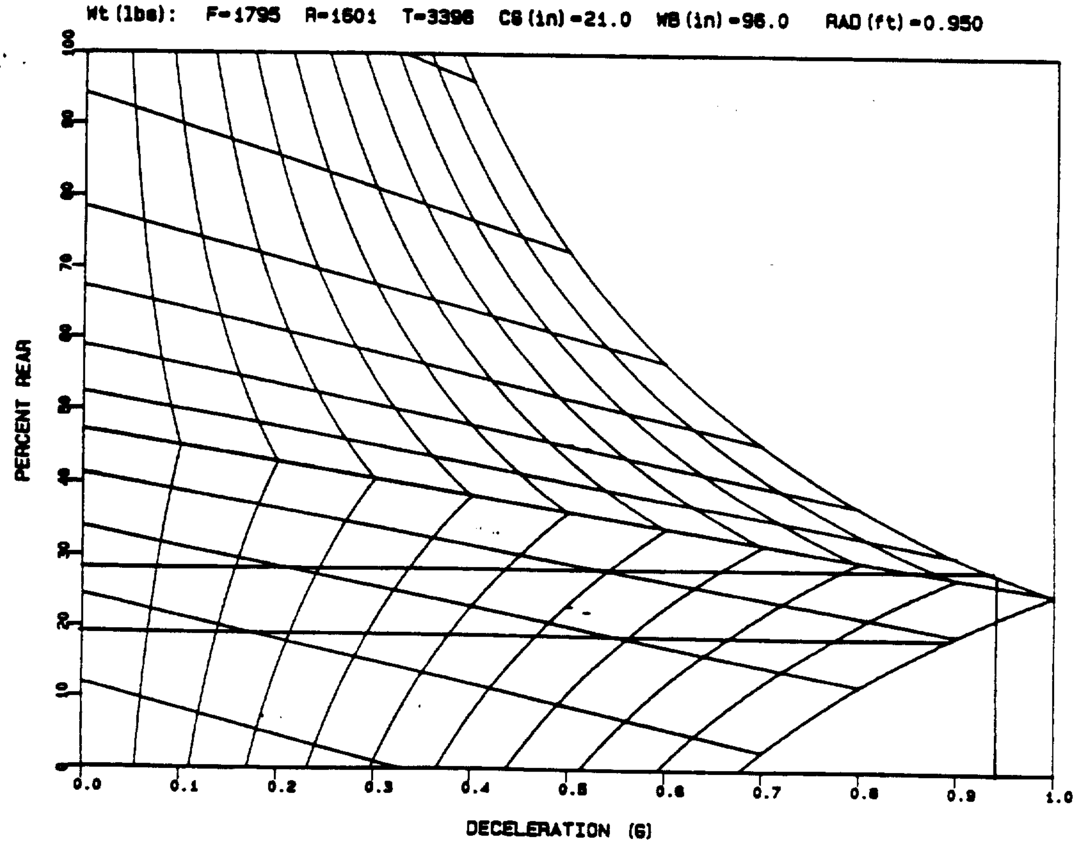


FIGURE 42

Mitsubishi Tredia Report 3

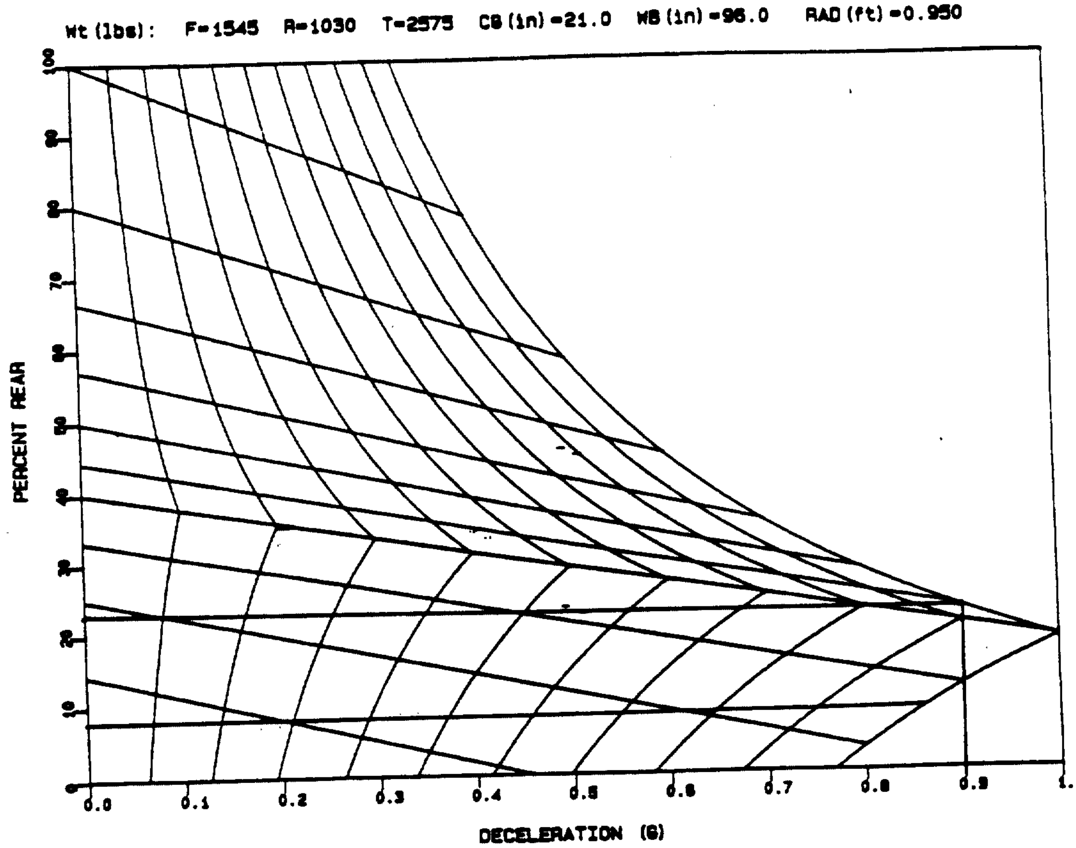


FIGURE 43

Nissan Pulsar Report 3

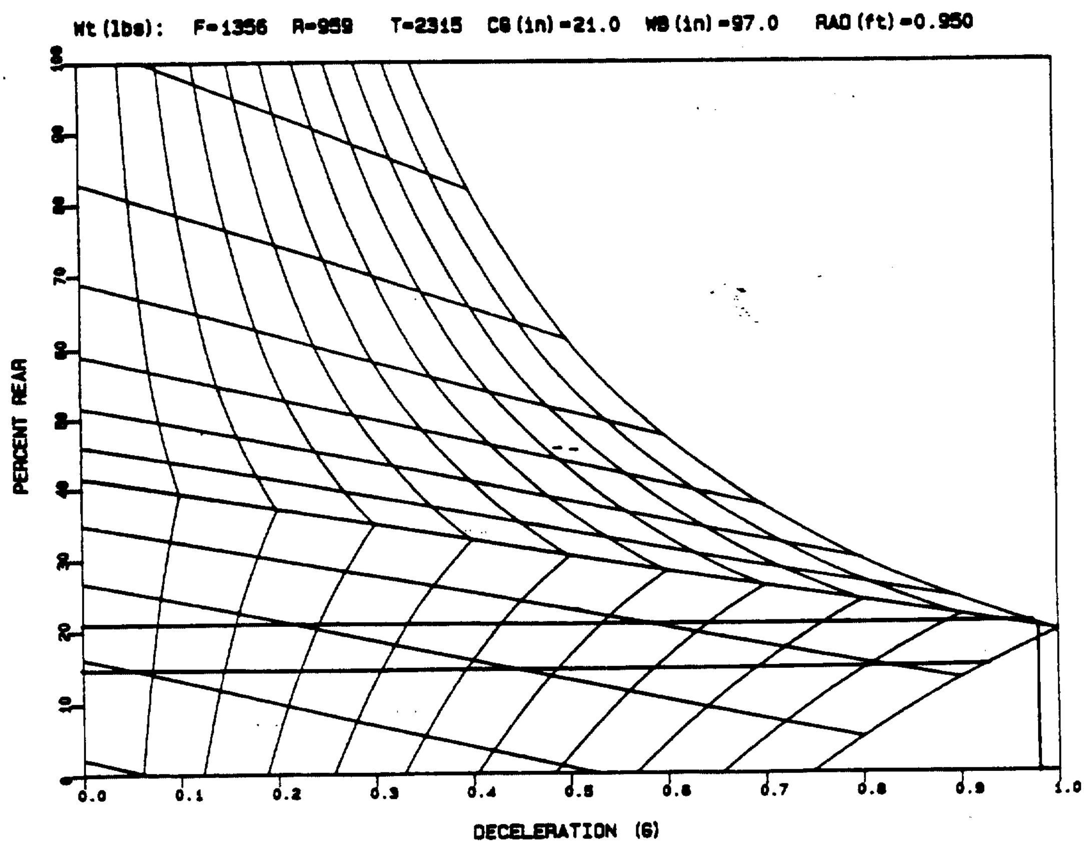


FIGURE 44

Plymouth Horizon Report 3

Wt (lbs): F=1720 R=970 T=2690 CG (in)=21.0 WB (in)=99.0 RAD (ft)=0.950

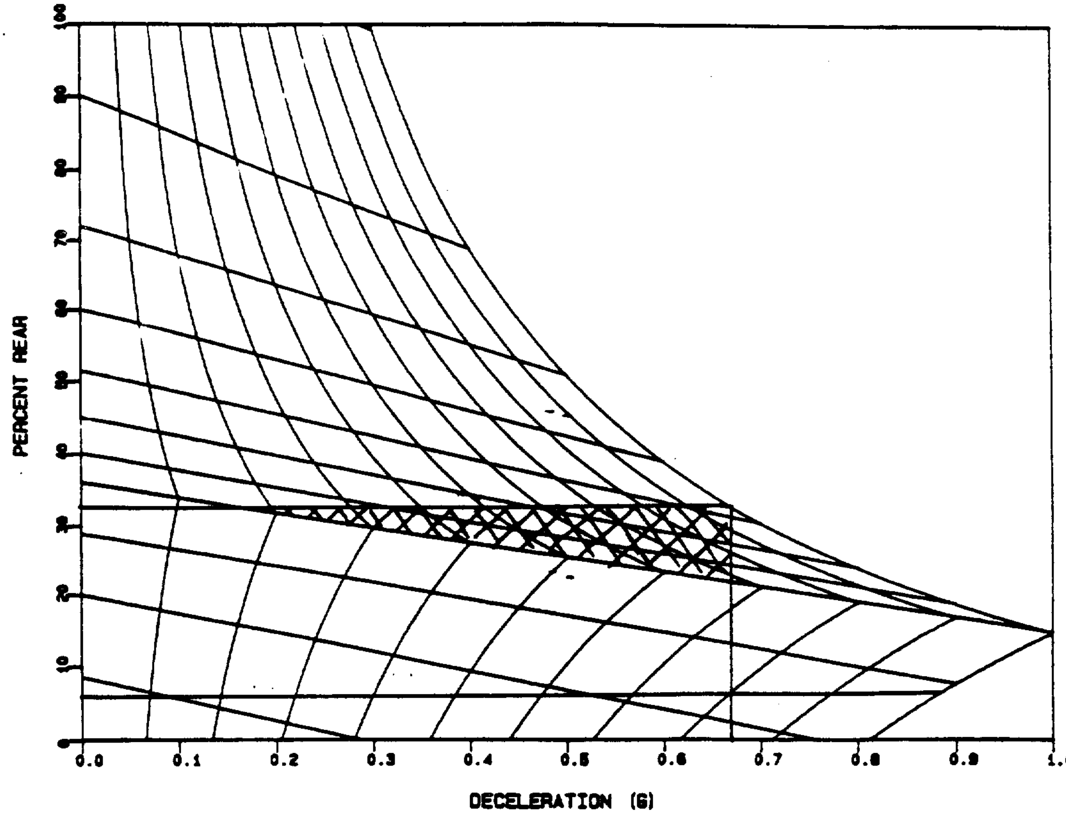


FIGURE 45

Subaru DL Report 3

Wt (lbs): F=1495 R=1100 T=2595 CG (in)=21.0 WB (in)=97.0 RAD (ft)=0.950

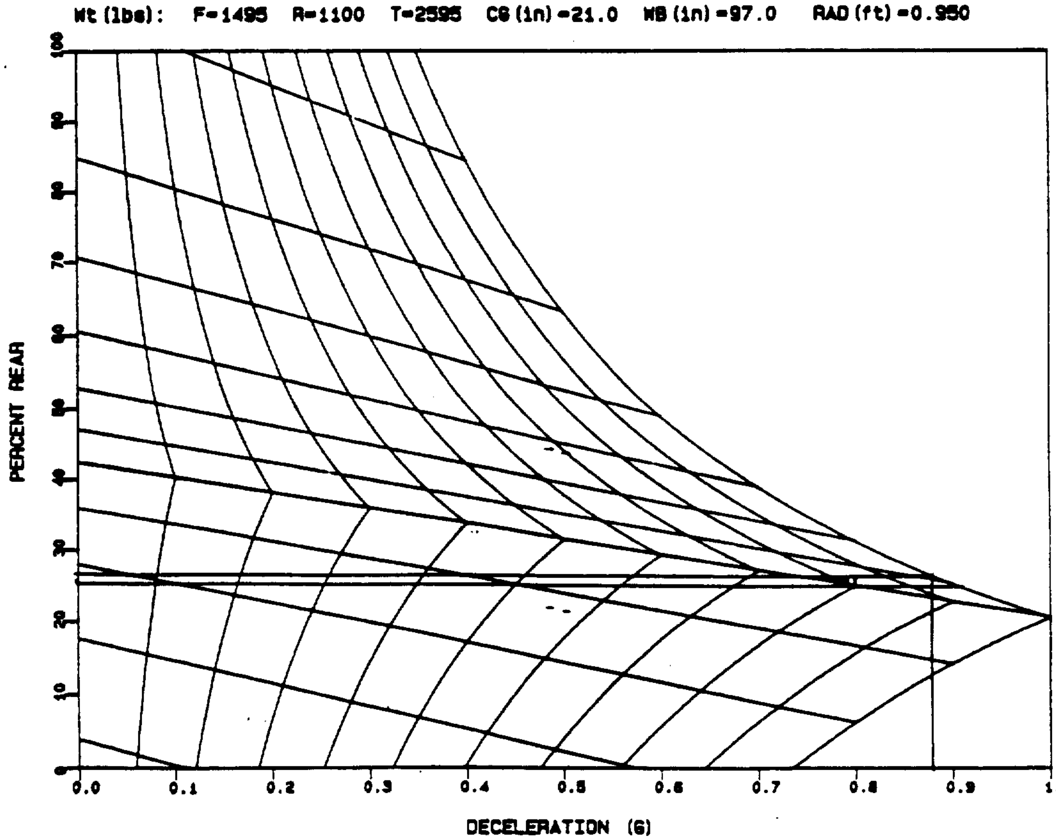


FIGURE 46

Toyota Camry Report 3

Wt (lbs): F=1724 R=1164 T=2888 CG (in)=21.0 WB (in)=102.0 RAD (ft)=0.950

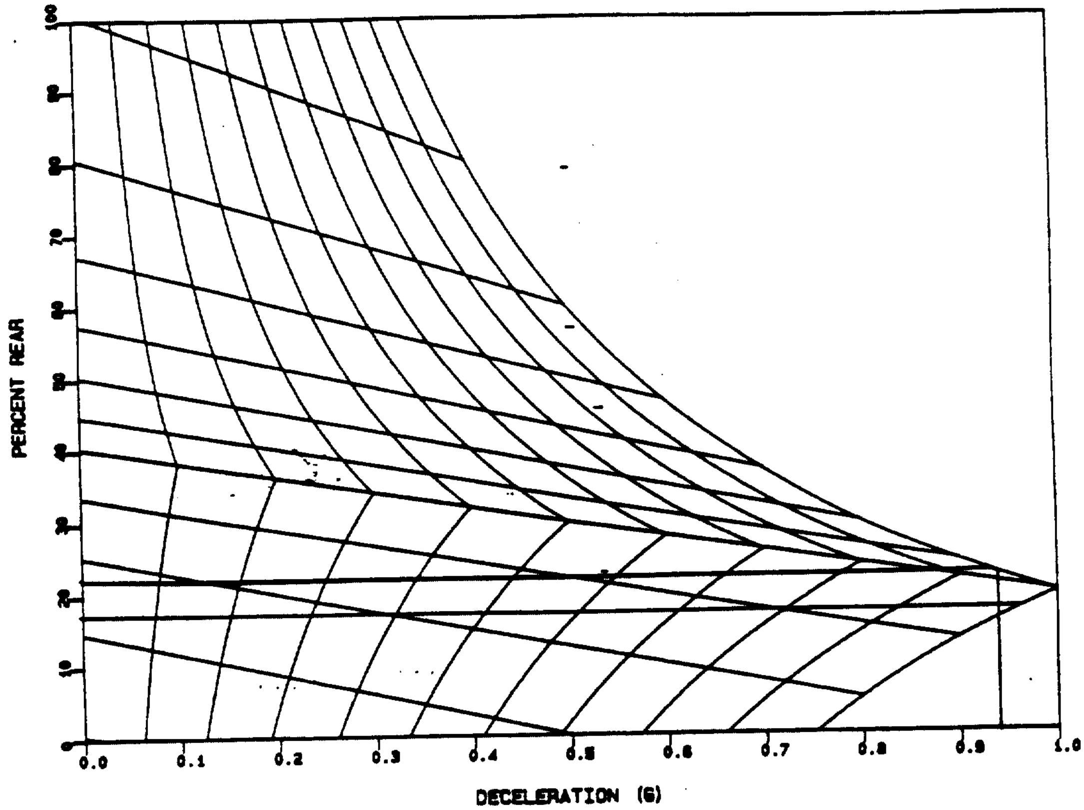


FIGURE 47

Toyota Cressida Report 3

Wt (lbs): F=1750 R=1479 T=3229 CG (in)=21.0 WB (in)=104.0 RAD (ft)=0.950

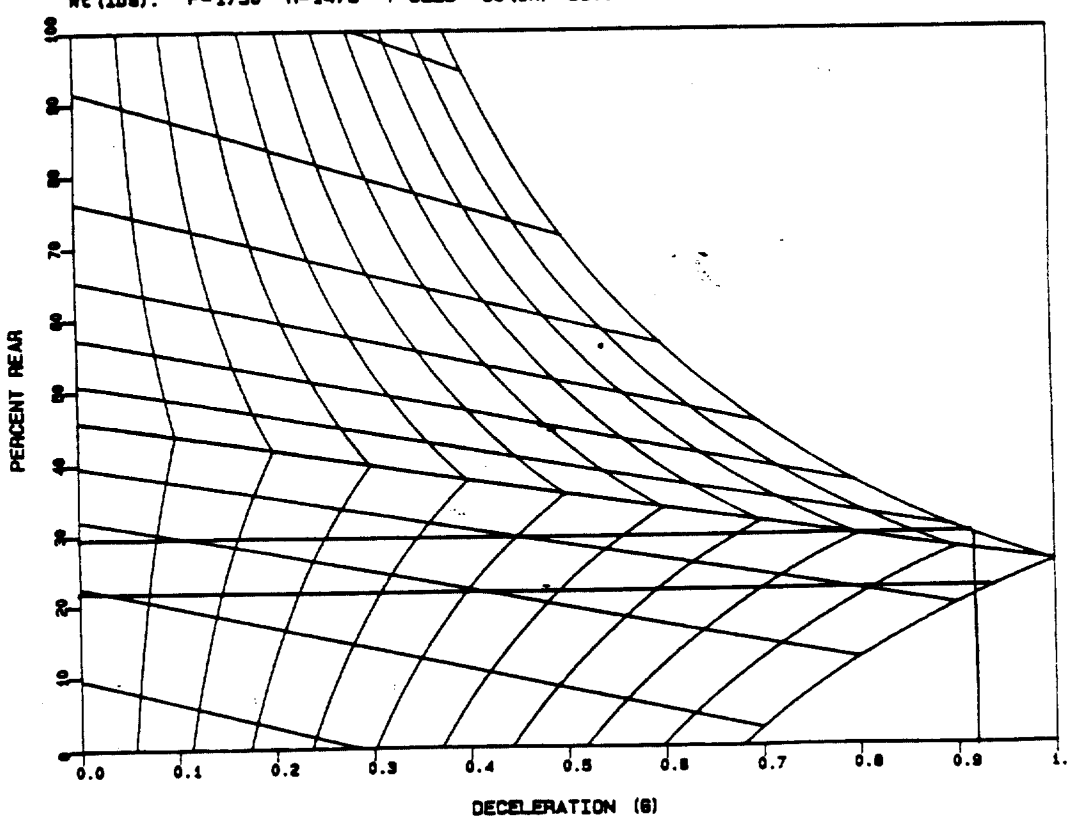


FIGURE 48

Volkswagen Rabbit Report 3

Wt (lbs): F=1411 R=911 T=2322 CG (in)=21.0 WB (in)=94.0 RAD (ft)=0.950

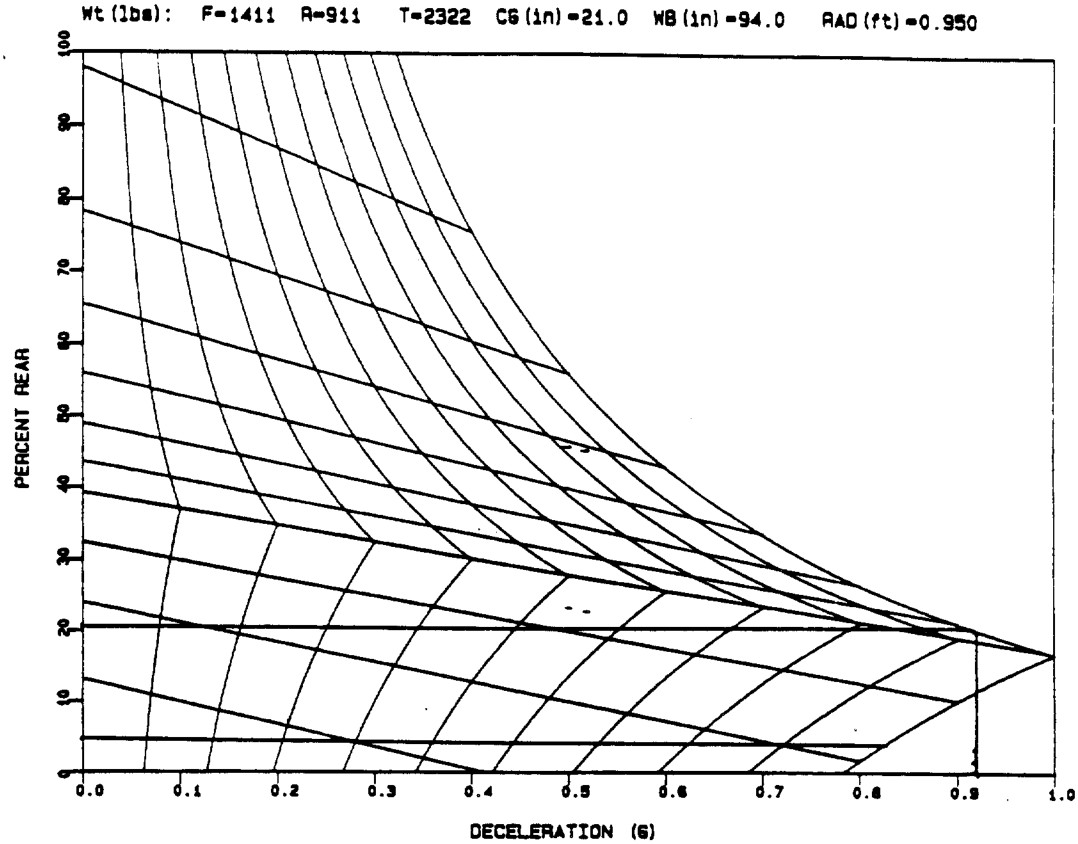


FIGURE 49

Volvo GL Report 3

Wt (lbs): F=1746 R=1570 T=3316 CG (in)=21.0 WB (in)=104.0 RAD (ft)=0.950

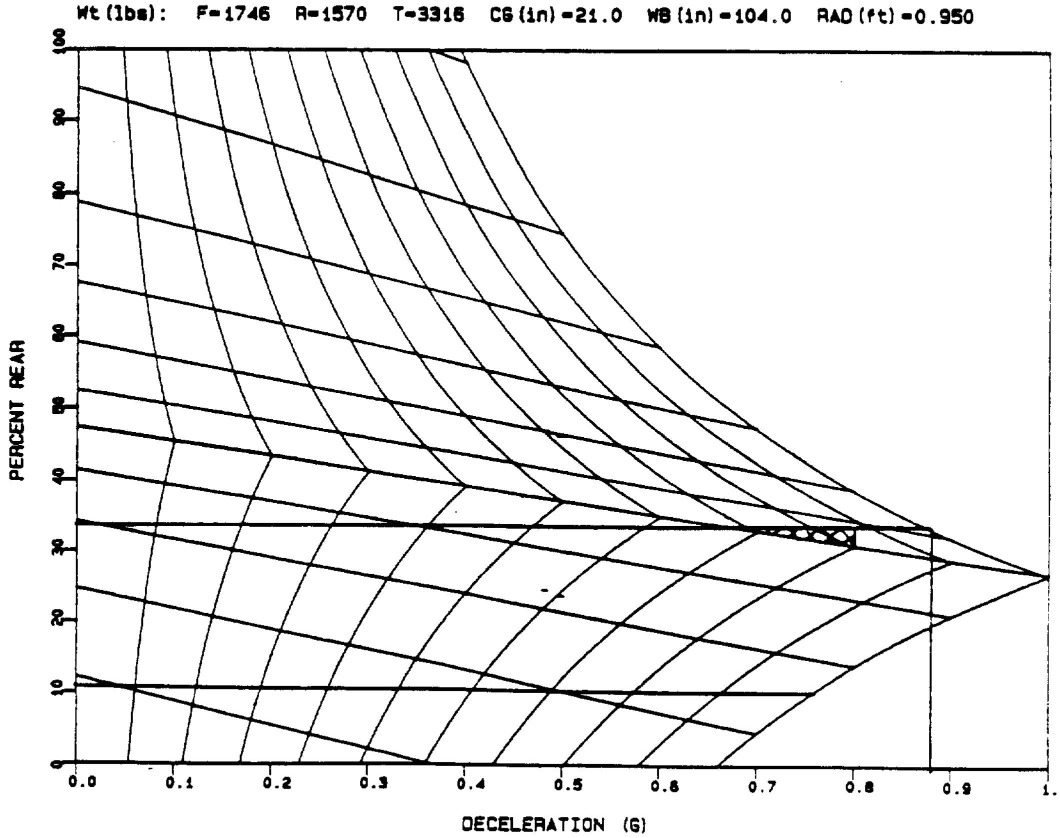


FIGURE 50

Chevrolet Cavalier Report 4

Wt (lbs): F=1971 R=1021 T=2992 CG (in)=21.0 WB (in)=100.0 RAD (ft)=0.950

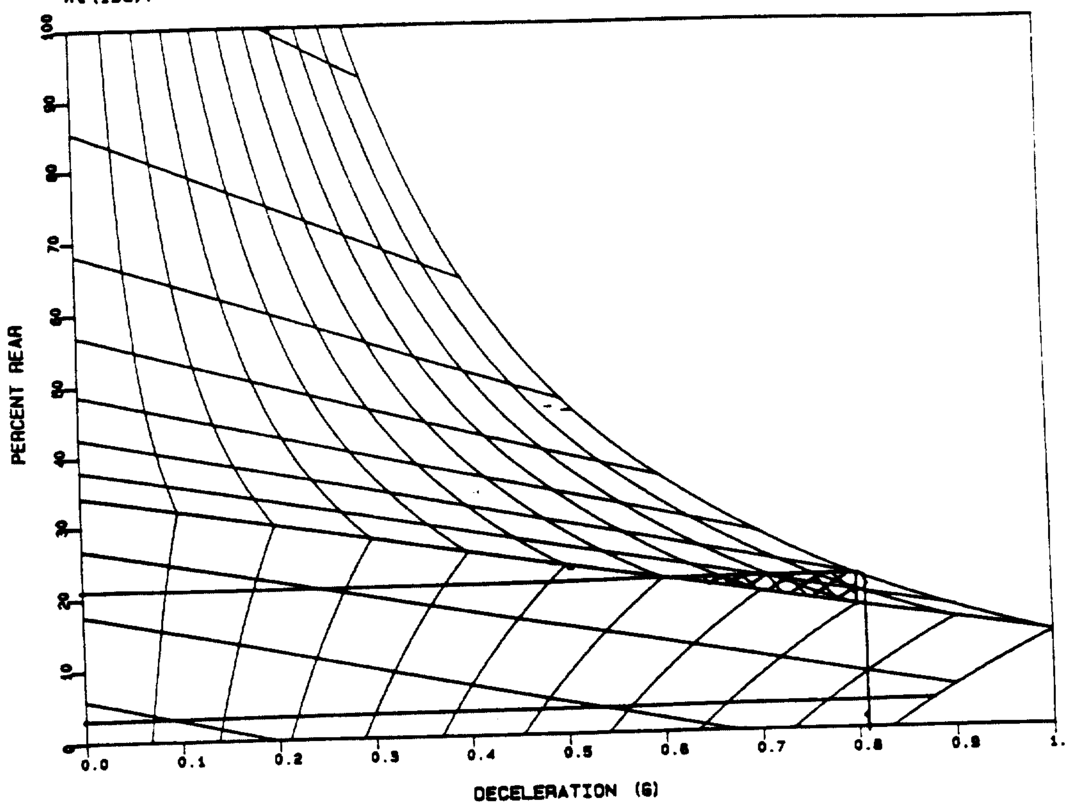


FIGURE 51

Dodge 600 Report 4

Wt (lbs): F=1779 R=1151 T=2930 CG (in)=21.0 WB (in)=103.0 RAD (ft)=0.950

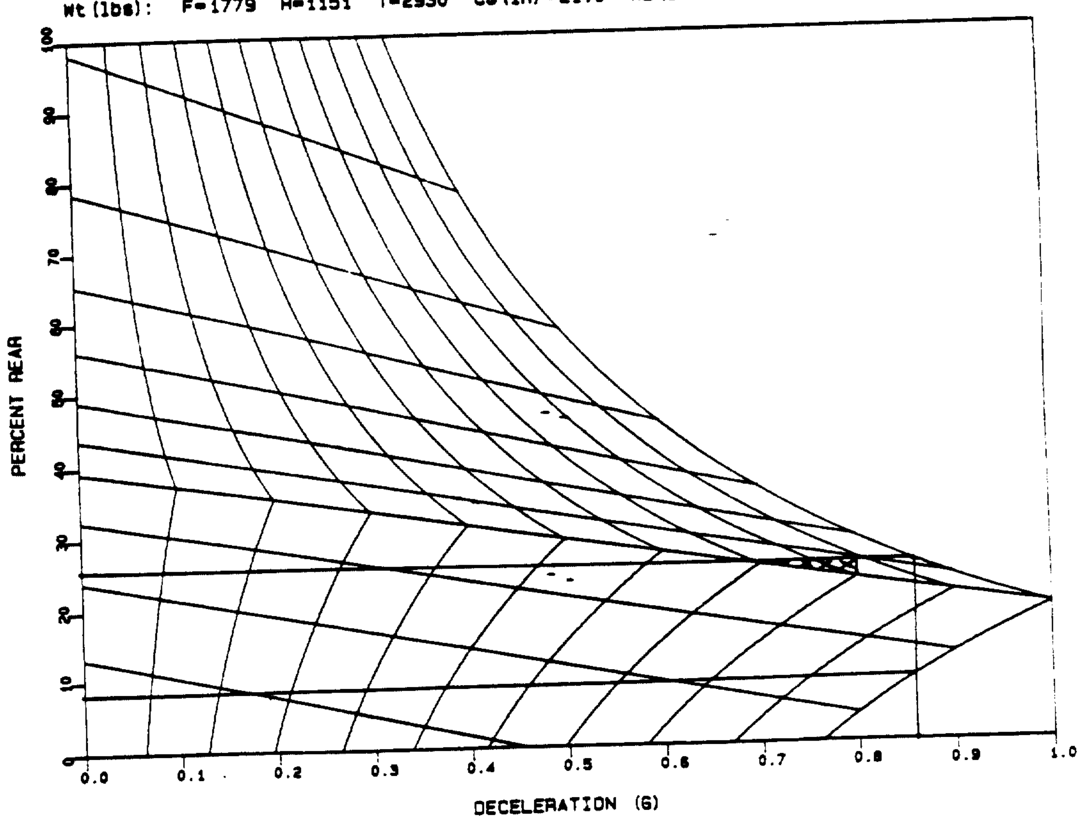


FIGURE 52

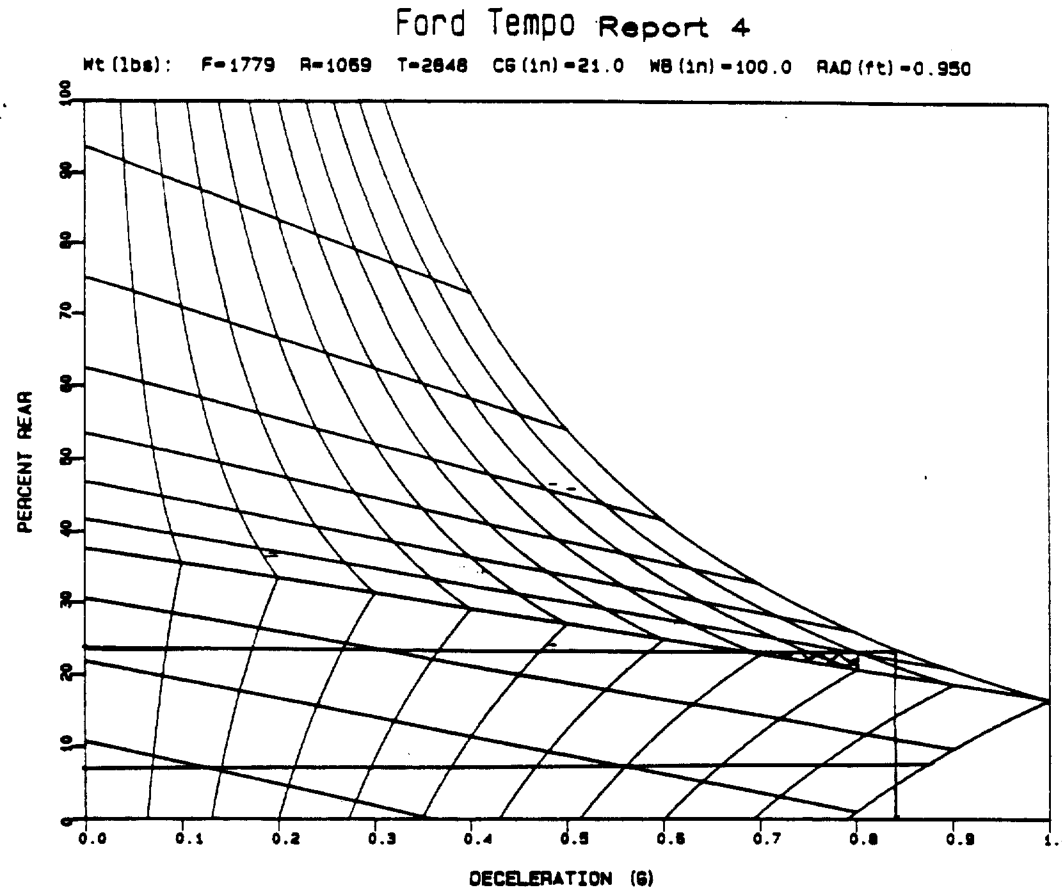


FIGURE 53

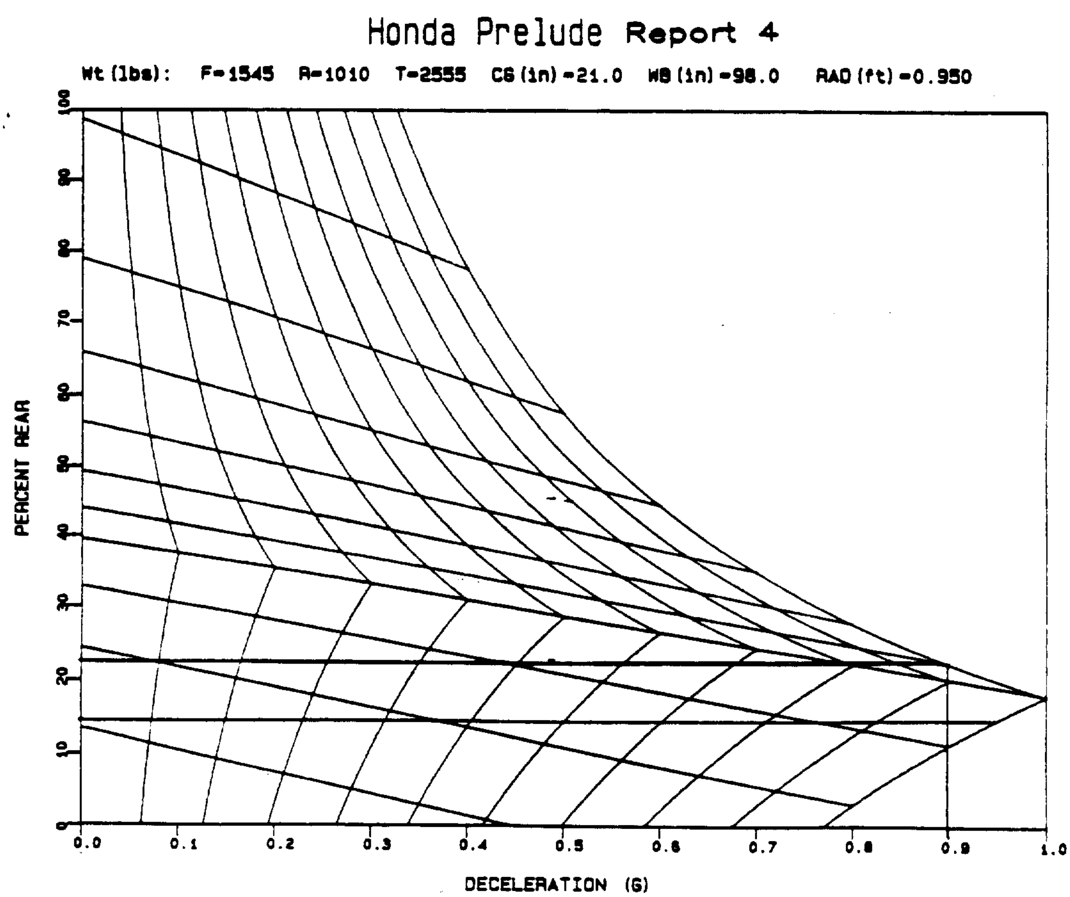


FIGURE 54

Isuzu Impulse Report 4

Wt (lbs): F=1715 R=1360 T=3075 CG (in)=21.0 WB (in)=95.0 RAD (ft)=0.950

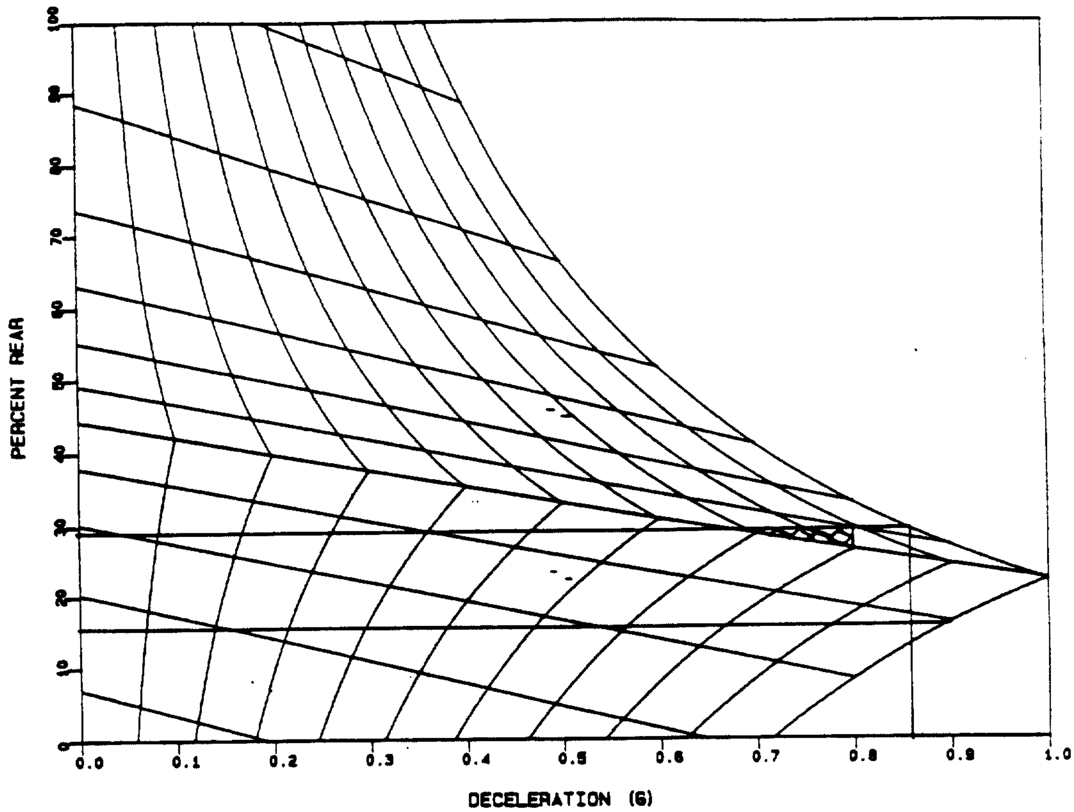


FIGURE 55

Mazda-Toyo-Kogyo 626D Report 4

Wt (lbs): F=1601 R=1080 T=2681 CG (in)=21.0 WB (in)=105.0 RAD (ft)=0.950

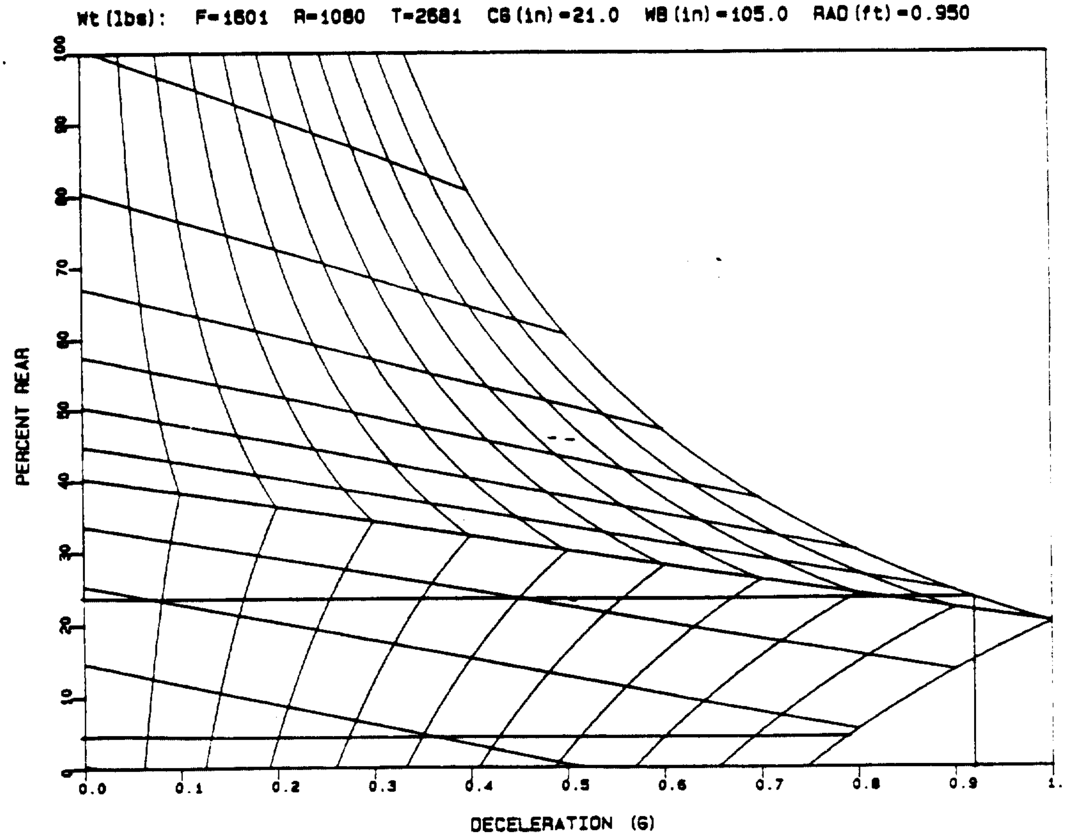


FIGURE 56

Mitsubishi Tredia Report 4

Wt (lbs): F=1545 R=1030 T=2575 CG (in) =21.0 WB (in) =96.0 RAD (ft) =0.950

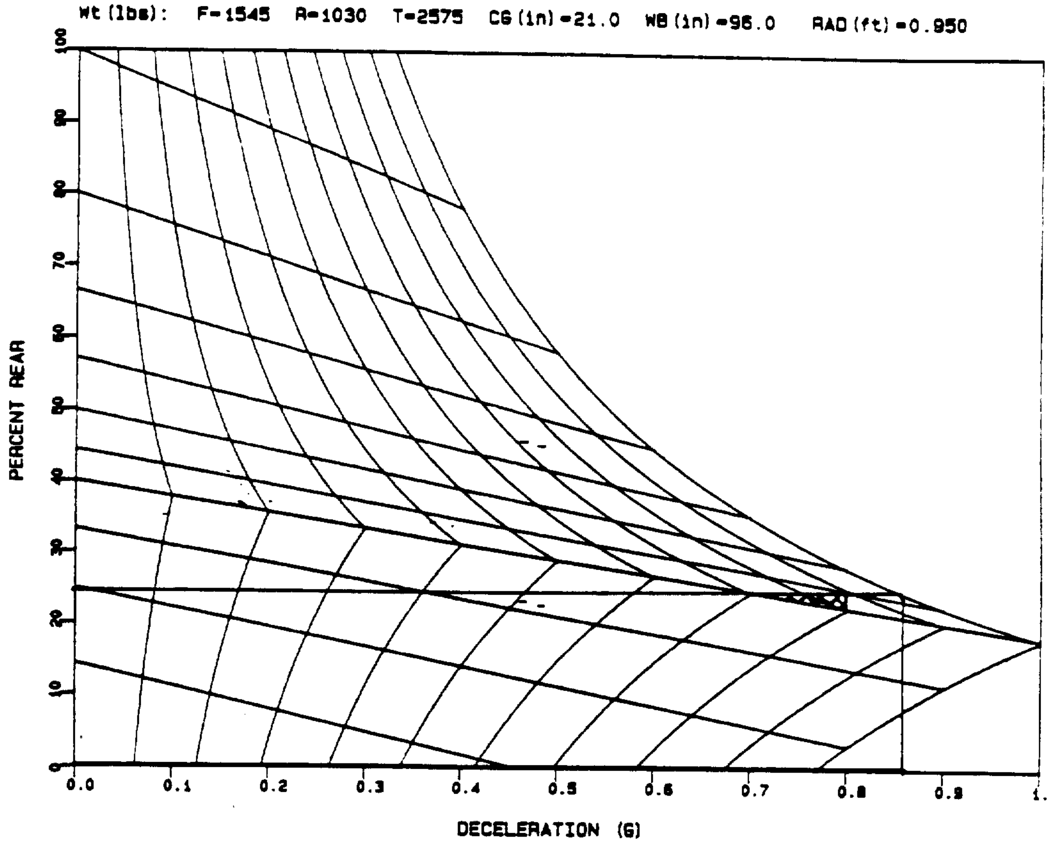


FIGURE 57

Nissan Pulsar Report 4

Wt (lbs): F=1356 R=959 T=2315 CG (in) =21.0 WB (in) =97.0 RAD (ft) =0.950

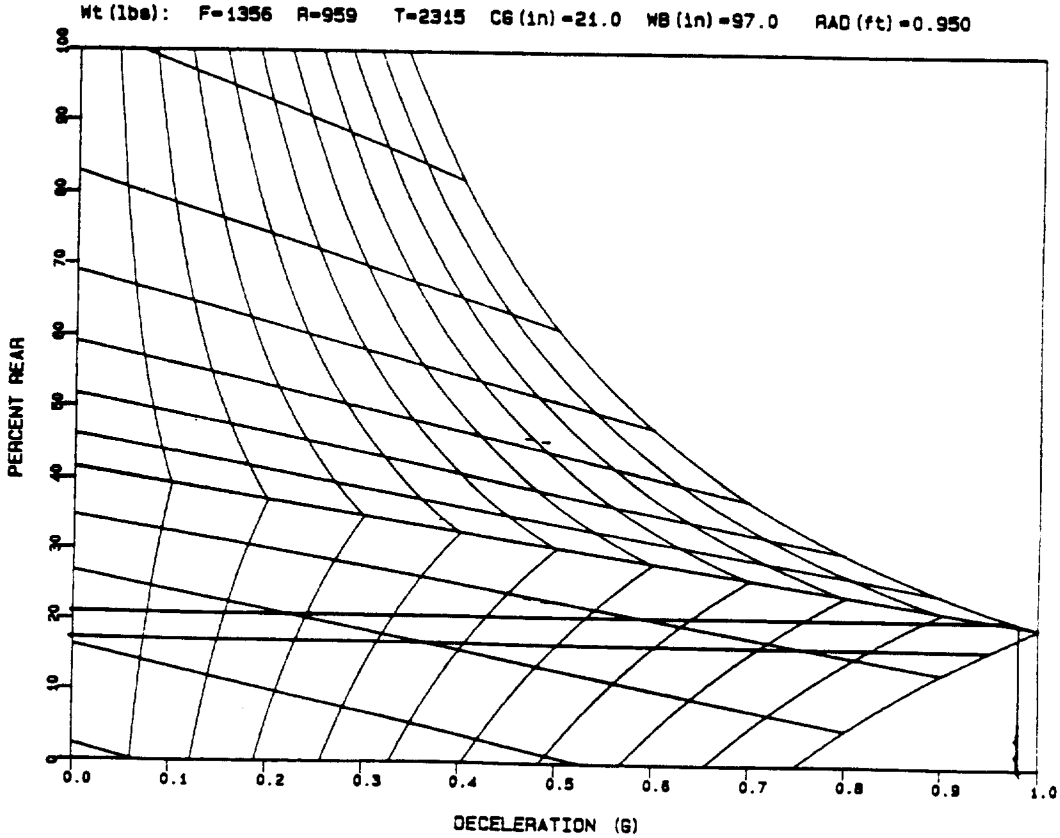


FIGURE 58

Subaru DL Report 4

Wt (lbs): F=1495 R=1100 T=2595 CG (in)=21.0 WB (in)=97.0 RAD (ft)=0.950

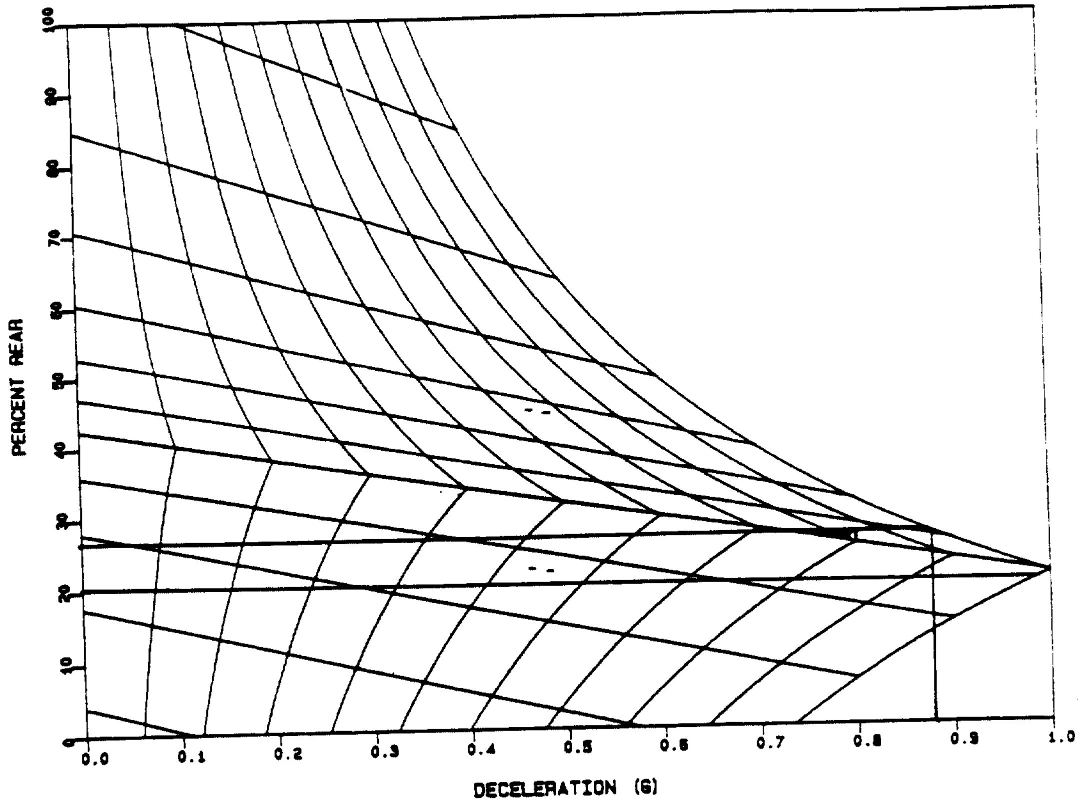


FIGURE 59

Toyota Camry Report 4

Wt (lbs): F=1724 R=1164 T=2888 CG (in)=21.0 WB (in)=102.0 RAD (ft)=0.950

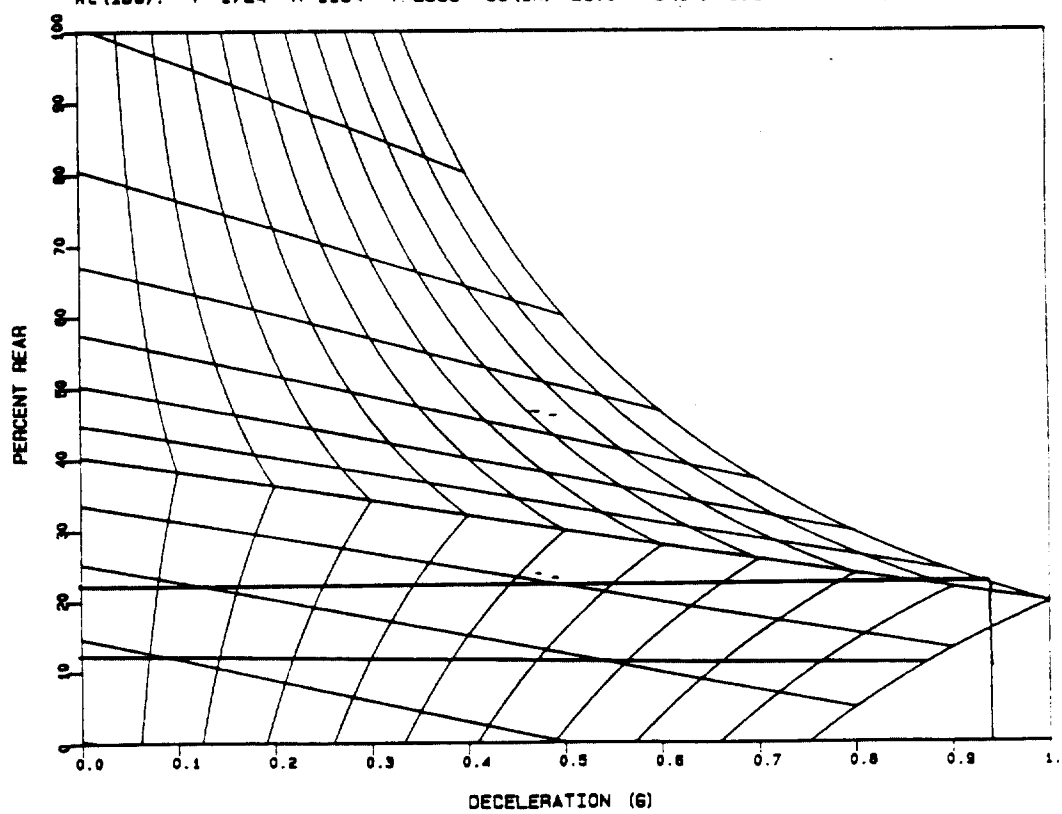


FIGURE 60

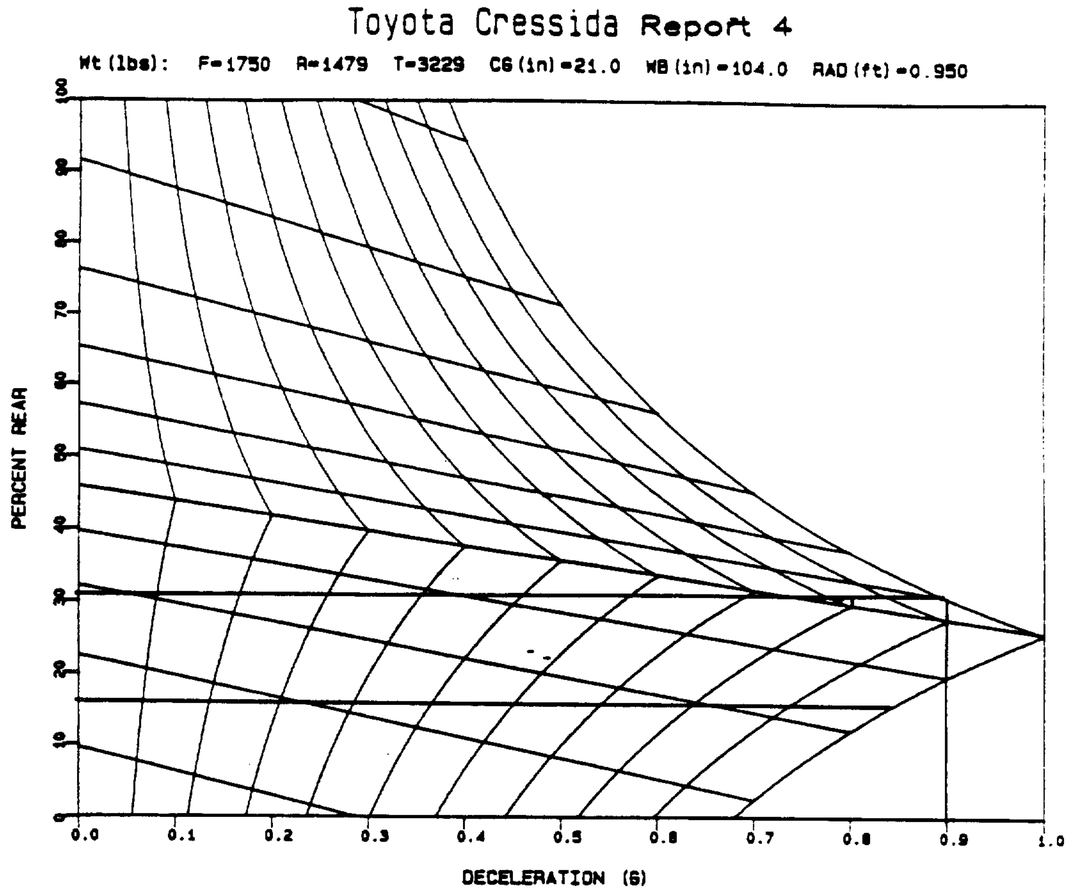


FIGURE 61

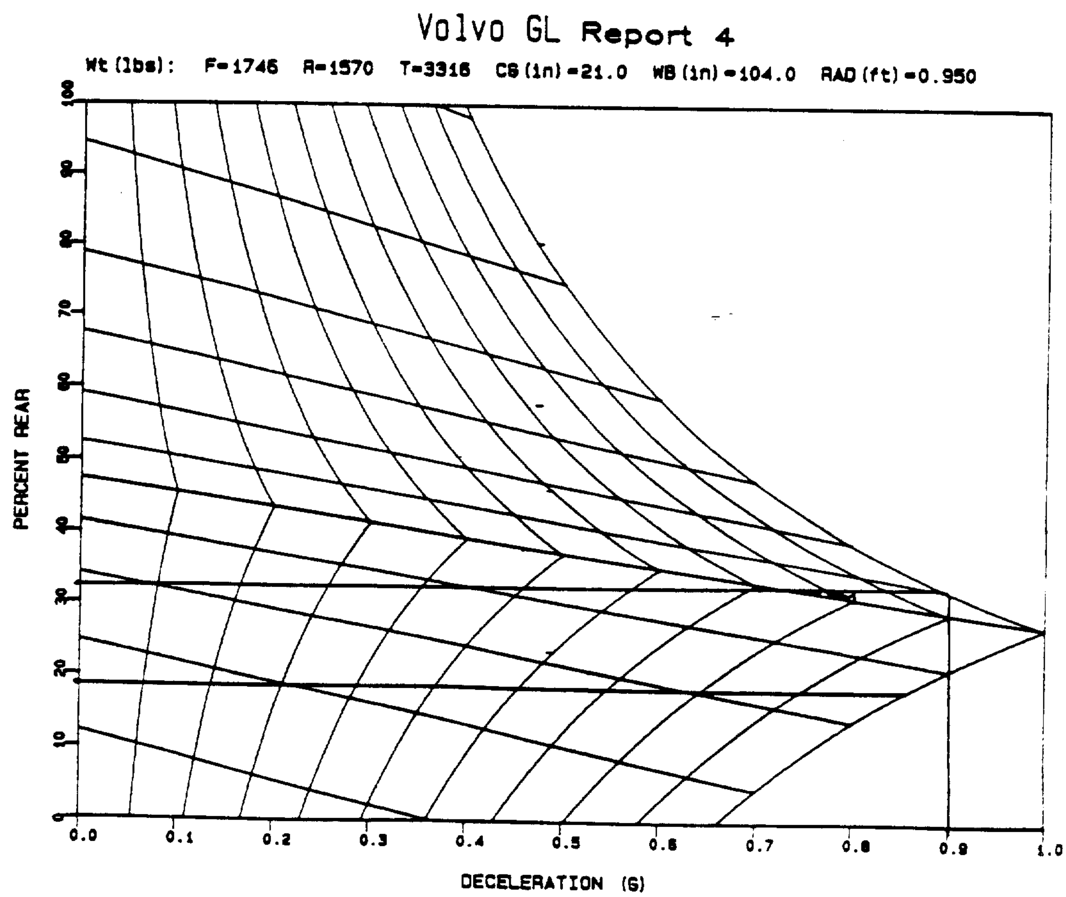


FIGURE 62

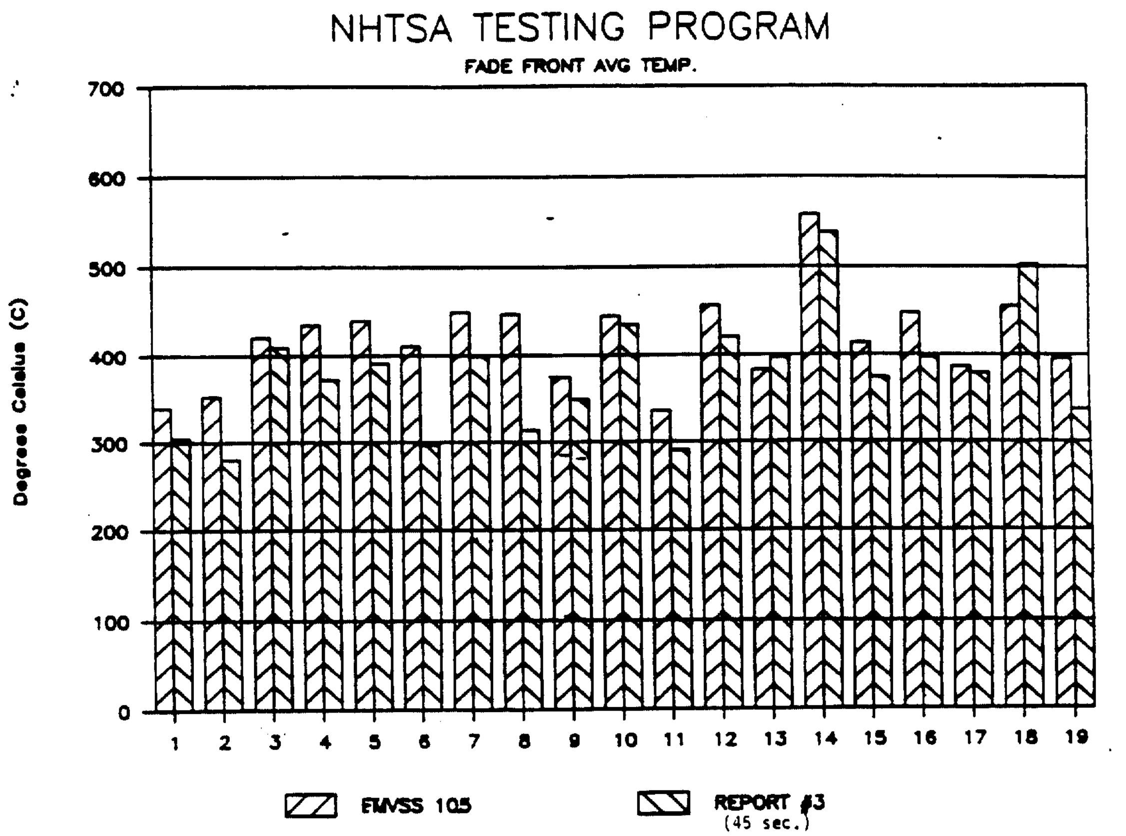


FIGURE 63

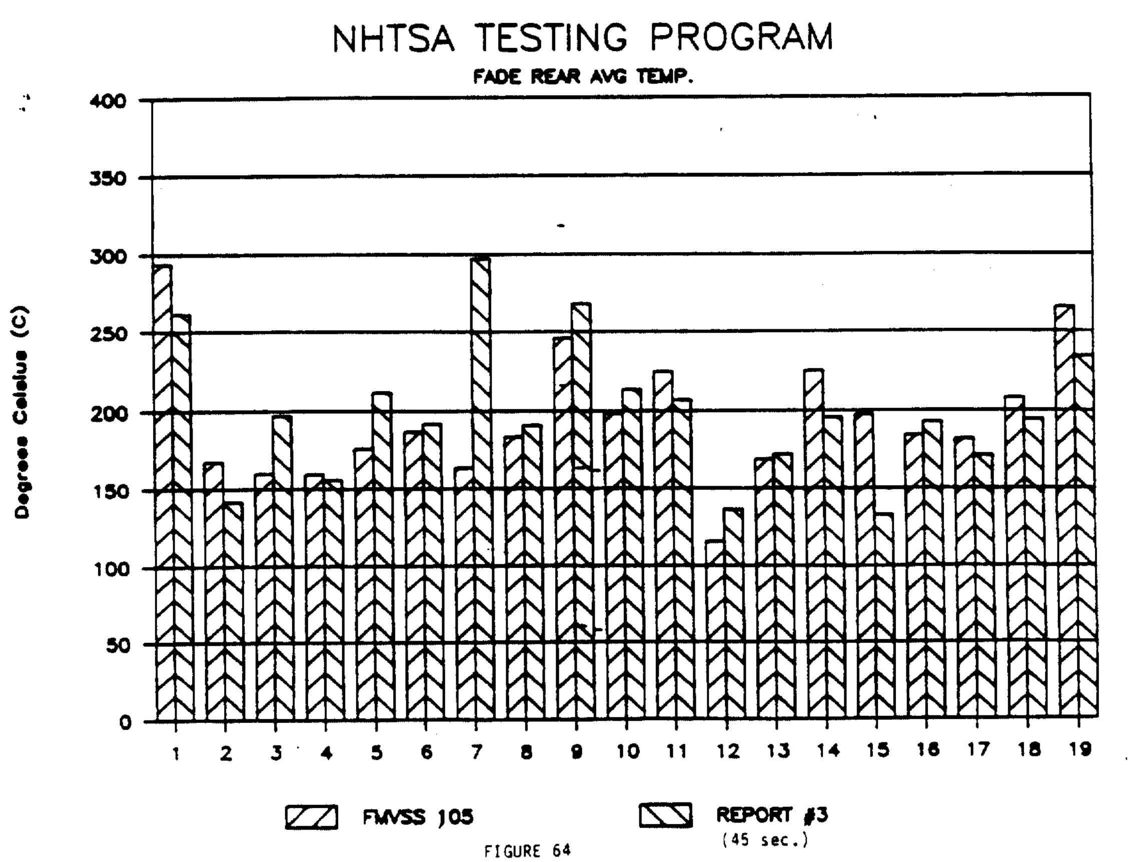


FIGURE 64

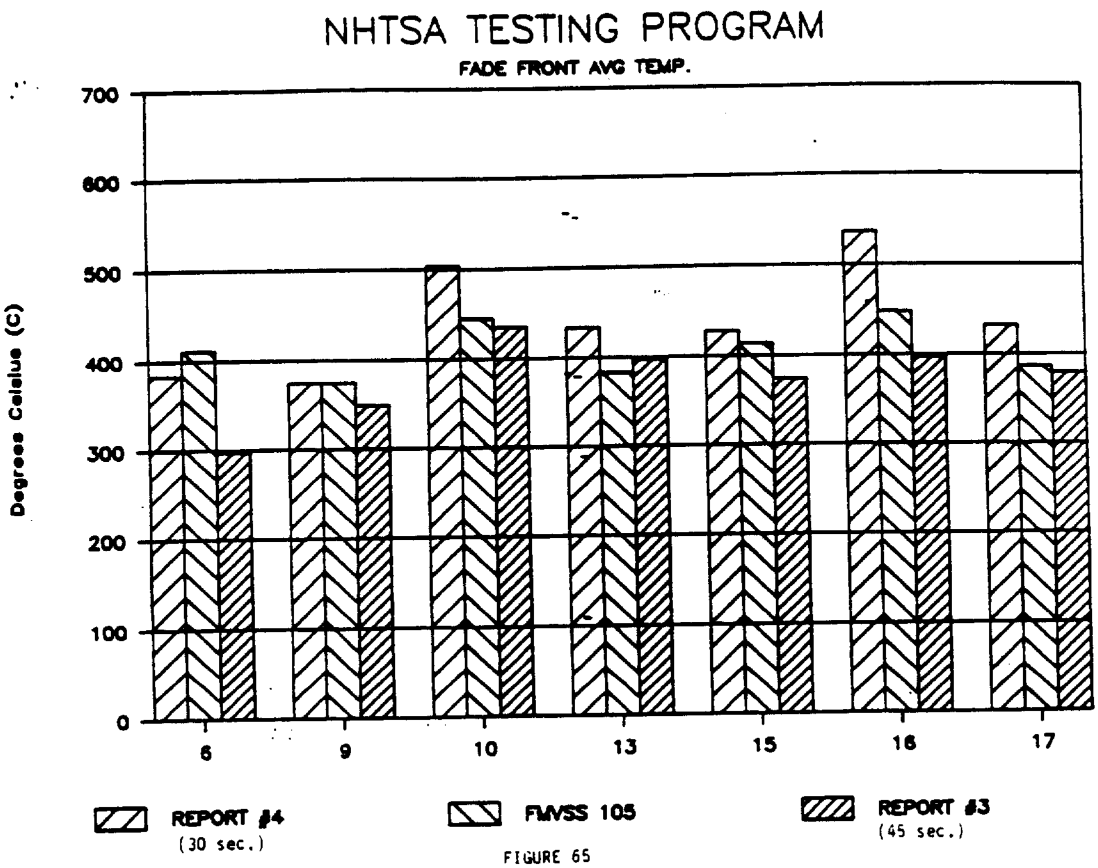


FIGURE 65

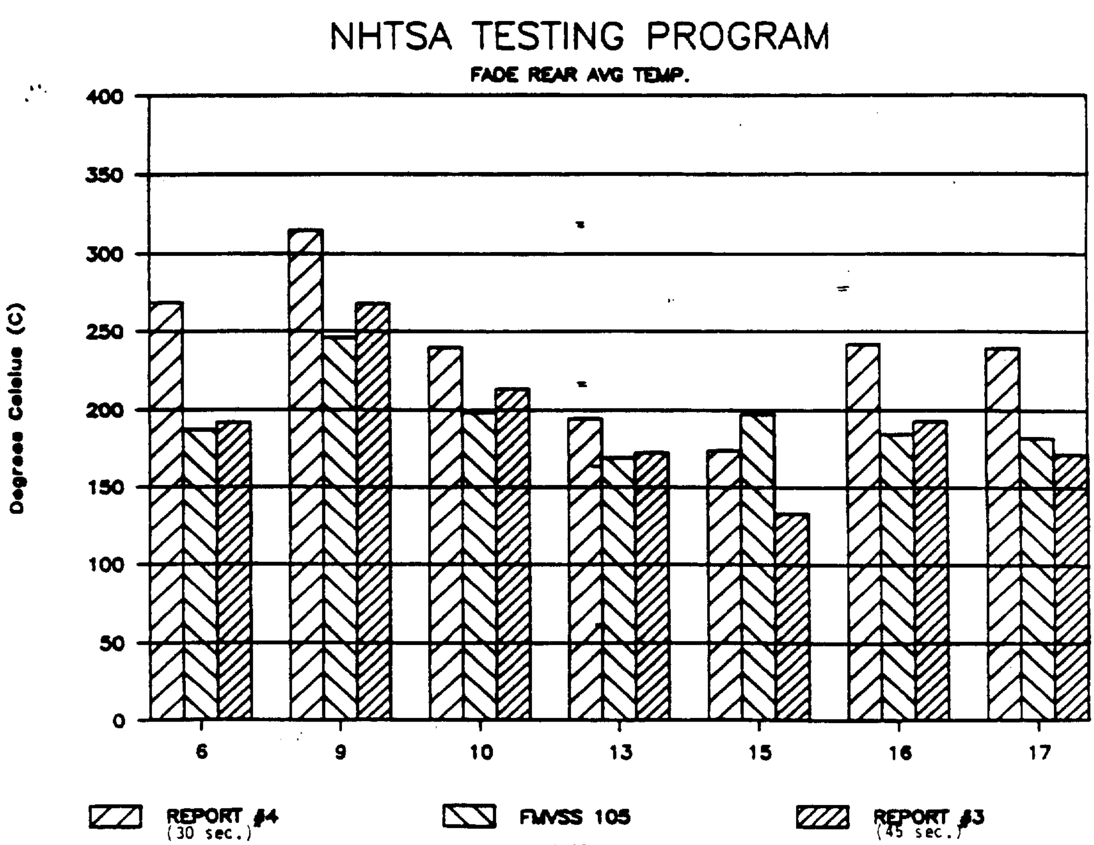


FIGURE 66

NHTSA TESTING PROGRAM

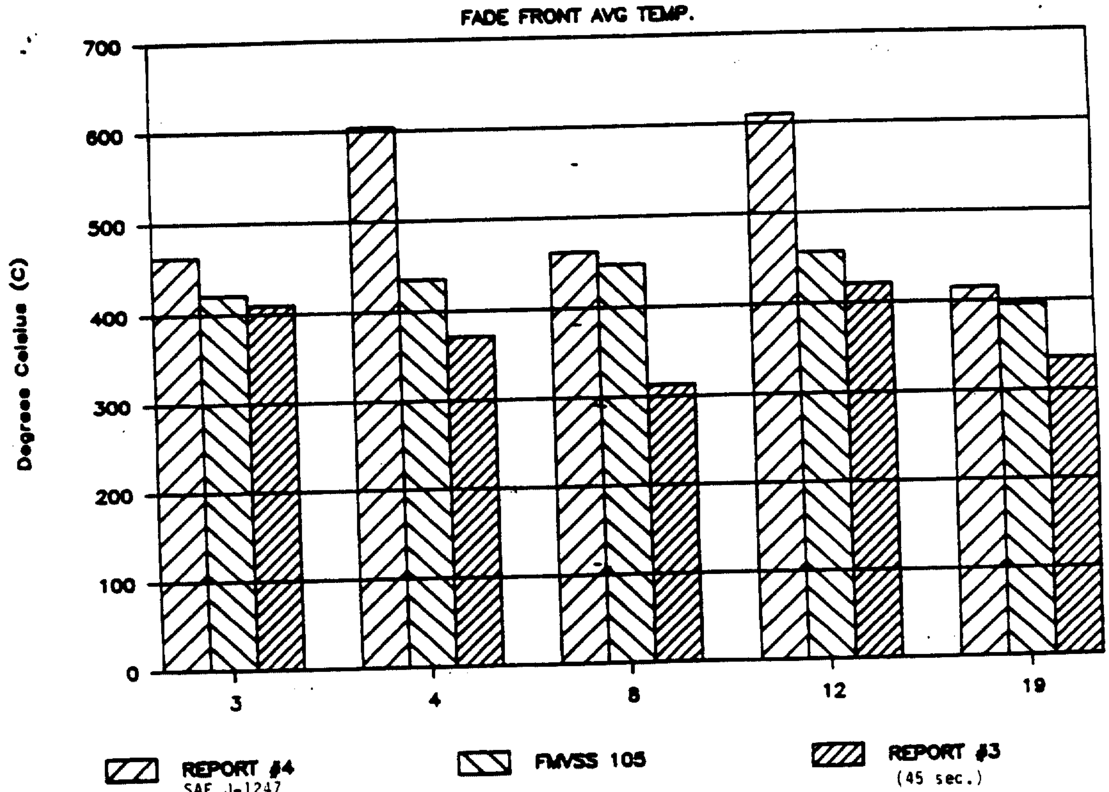


FIGURE 67

NHTSA TESTING PROGRAM

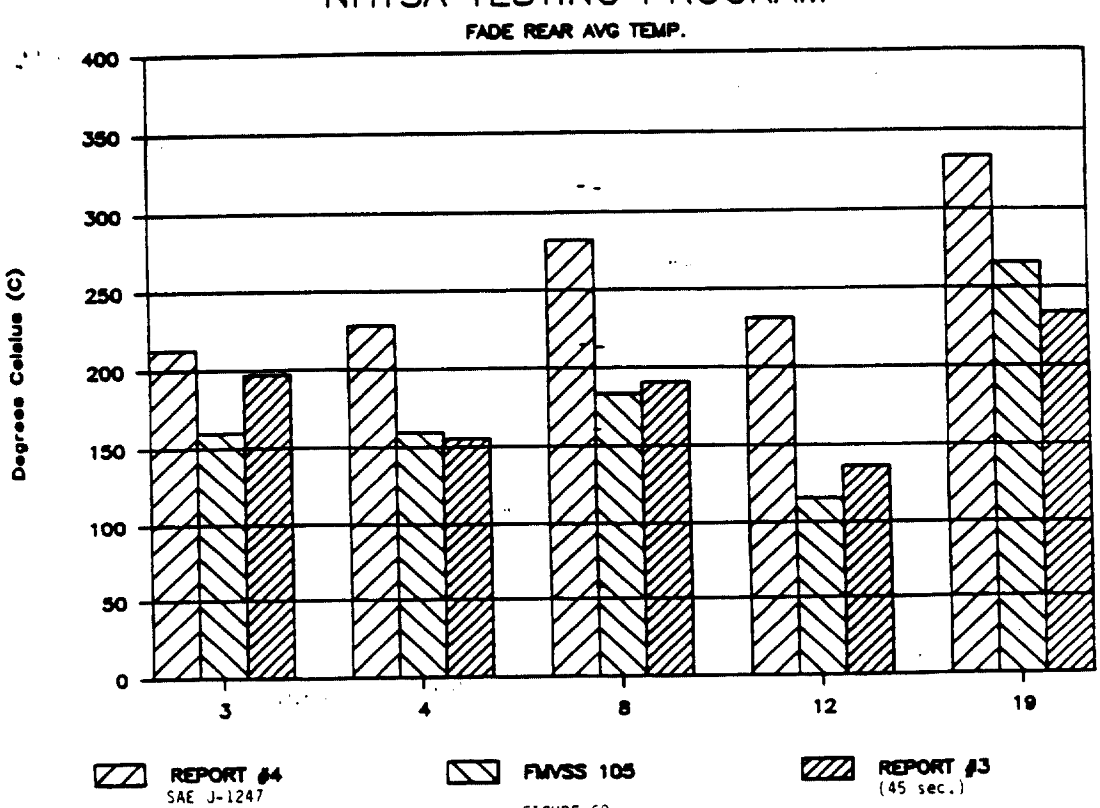


FIGURE 68

NUMBER OF ATTEMPTS ALLOWED

OBJECTIVE

The purpose of this Appendix is to review the impact of allowing only four test stop attempts to achieve the best stopping distance for each effectiveness requirement.

CONCLUSION

Reducing the allowed number of attempts to achieve the best stop for each effectiveness requirement from 6 to 4, as proposed in FMVSS 135, represents a increase in stringency over FMVSS 105. This provision of FMVSS 135, when coupled with the prohibition of any wheel lock during effectiveness tests, would have a significant impact on the difficulty encountered in compliance testing, with the result being an expected increase in the average length of stops measured in effectiveness tests.

RECOMMENDATIONS

1- Give due recognition to the effect of four stops instead of six when considering the stopping distances to be required.

2- Allow locked wheel stops to be ignored or aborted without being counted as one of the four attempts to meet the stopping distance.

DISCUSSION

FMVSS 135 proposes a reduction in the allowed number of attempts from six in FMVSS 105 to four. In addition, FMVSS 135 proposes to disallow any wheel lock at speeds greater than 15 km/h (9.3

mph). These are significantly different test conditions than in FMVSS 105 which allows a single wheel to lock at any speed, and any number of wheels to lock at speeds below 10 mph (16.1 km/h).

During the GM test program conducted for this response, a total of six complete FMVSS 105 tests were conducted by experienced drivers and in vehicles with complete instrumentation including torque wheels and digital data acquisition equipment. This instrumentation allowed verification of wheel lock, and provided a completely independent means of assessing the driver's ability to achieve the best stopping distance while meeting all other requirements of FMVSS 105. During a 105 test, the driver is afforded six attempts at effectiveness requirements a total of seven different times; during first effectiveness tests from 30 and 60 mph (48.3 and 96.5 km/h), during second effectiveness tests from 30 and 60 mph (only 4 attempts are allowed from 80 mph (128.8 km/h), during third effectiveness tests from 60 mph, and during fourth effectiveness tests from 30 and 60 mph.

Given that six complete FMVSS 105 tests were run, a total of 42 trials were made, with six stops each. To determine the significance of reducing the allowed number of attempts from six to four, these 42 occasions were studied to determine which of the six stops produced the shortest stopping distance. The results of this analysis are shown in figure 1. Here we see that in more than 45% of the occasions during the GM vehicle tests, the best stopping distance was achieved in either the fifth or sixth stop, both of which would be eliminated under FMVSS 135.

The magnitude of the stopping distance penalty is also important. A further review of the GM testing calculated the best stopping distance achieved in the first four stops, and compared that to the best stop achieved in stops five or six. The results of this comparison are shown in figure 2. Here we see that in several test portions the best stopping distance the driver was able to achieve in the first four stops was more than 5 feet (1.5 m) longer than the distance achieved in stops five or six. There were three occasions where the penalty associated with reducing the number of stops was 10 feet (3 m) or more. In two of the six vehicle tests, test requirement compliance was not achieved until either the fifth or sixth stop, and thus two of the vehicles would have failed the requirements of FMVSS 105 if only four stops had been allowed. On only one occasion, was the stopping distance achieved in stops five or six longer than that achieved in the first four stops, and on that occasion the difference was less than 2 feet (0.6 m). Over the 42 occasions that were encountered during the GM tests, the average stopping distance penalty associated with reducing the allowed number of attempts from six to four was 3.2 feet (0.98 m).

In order to achieve true equivalency with FMVSS 105, the performance requirements of FMVSS 135 should be lengthened by 3.2 feet (0.98 m), according to our data, to properly account for the reduction in the number of attempts allowed for each effectiveness requirement. Failure to properly correct for this reduction in allowed number of attempts would result in an increase in stringency over FMVSS 105 requirements.

A vehicle brake system undergoes tremendous abuse during a certification test, and the system performance may change substantially as a result of the exposure to high temperatures and high energy stops during the test. Consequently, even the most experienced and skilled test drivers will encounter difficulty in achieving optimum vehicle stopping distance with only four attempts allowed.

If this reduction in the number of attempts is coupled with the added proviso of FMVSS 135 that prohibits any wheel lock regardless of vehicle speed, then the driver's task becomes doubly difficult. A very likely consequence of the prohibition of one wheel lock is that tests that are very nearly completed would have to be scrapped. This would easily happen if a driver had difficulty determining the optimum pedal apply, and either locked a wheel or missed the stopping distance on the first three stops. If he over-compensates by either backing off or applying too much force, the test would either be failed or ruled invalid. In each case, the fault would be driver error rather than vehicle design, and the vehicle would have to be rebuilt and equipped with new tires and started over; a complete waste of time that can be avoided by allowing one wheel lock or allowing aborting and not counting attempts where one wheel locks.

General Motors would not have an objection to a reduction in the number of attempts at each effectiveness requirement from six to four, in the interest of promoting harmonization, provided that stopping distances are adjusted and a locked wheel stop could be simply discarded or aborted rather than counting as one of the four test attempts. This minor modification would meet the spirit of harmonization, and yet allow the test driver to deliver the optimum vehicle performance at any given test stage.

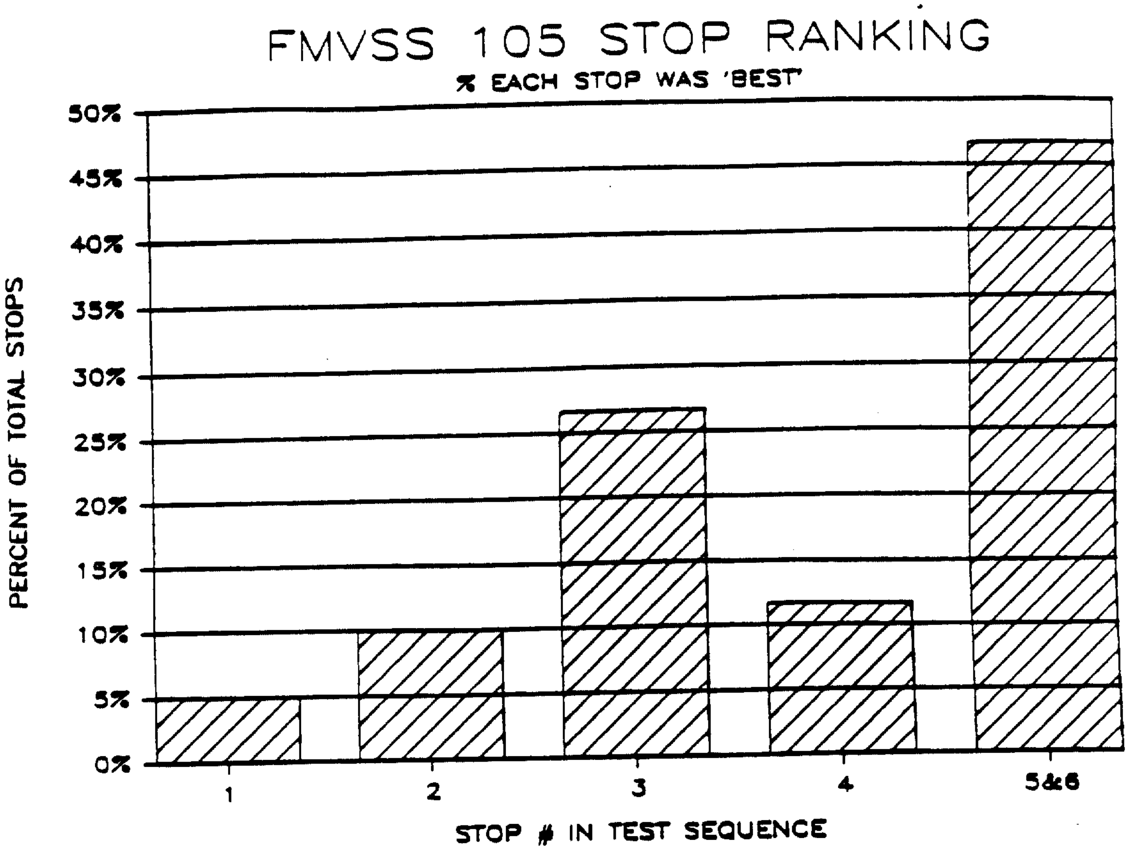


Figure 1

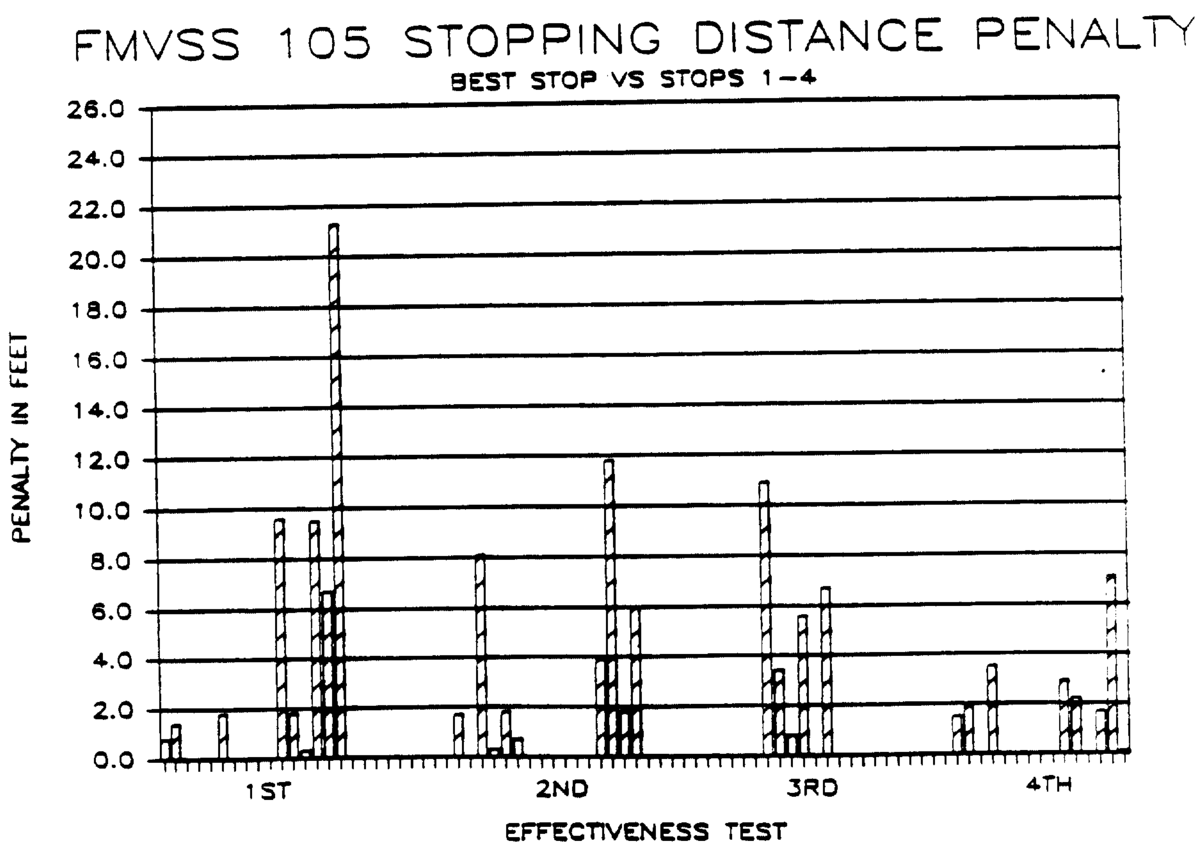


Figure 2

PRE-BURNISHED BRAKE EFFECTIVENESS

OBJECTIVE

The purpose of this Appendix is to to illustrate how an unrealistically stringent pre-burnish effectiveness requirement forces design compromises that may reduce burnished brake system performance.

CONCLUSIONS

1. Overly stringent pre-burnished stopping distance requirements (as proposed for FMVSS 135) preclude brake balance designs that would provide the best achievable stopping distances over the longer burnished life of the brake system. These requirements force vehicle designs optimized for Federal tests rather than customer needs.

2. The stringent pre-burnished requirement proposed for FMVSS 135 is design restrictive in that it forces the use of rear brake designs incorporating a large change of friction coefficient during burnish.

RECOMMENDATIONS

1. Eliminate the preburnish requirements. This would enable brake designers to provide better burnished stopping distances, and would promote harmonization. There would be no detriment to safety and overall customer brake performance may be improved.

2. If the agency cannot accept elimination of preburnish effectiveness requirements, then establish stopping distances sufficiently long to eliminate inappropriate design compromises.

DISCUSSION

GM is not aware of any domestic accident data or customer experience that would suggest a safety need for a pre-burnished or green brake effectiveness requirement. Moreover, the European community has built vehicles for many years with no green brake effectiveness requirement. That experience has not suggested a need for one. (Although GM is aware that NHTSA has data suggesting a somewhat higher accident involvement for new vehicles, we are not aware of any evidence that this phenomenon is linked to vehicle performance. It is at least as likely that the phenomenon is linked to driver unfamiliarity.)

General Motors is concerned that the pre-burnished effectiveness requirement which is proposed for FMVSS 135 would require a braking system which provides poorer performance over the life of the car than it could without the preburnish requirement. By requiring a very short stopping distance with brand new brakes and tires with the vehicle loaded to maximum capacity, FMVSS 135, as proposed, dictates longer stopping distances in the lightly loaded (or driver only) vehicle condition, during the break-in (burnish) period. This is due to the inevitable changes that occur in both tires and brakes as they break-in or burnish, combined with the types of brake friction materials and tires the manufacturer must use in order to balance the multitude of requirements, often conflicting, that are imposed by federal regulations and customer satisfaction.

To fully understand the stopping distance problem, one must recognize a few facts regarding the burnish behavior of brake friction materials and tires. With regard to brake friction materials, two general types are in use in commercial brake systems built for the North American market. These are (a) asbestos reinforced and (b) metal fiber reinforced. These two types are generally referred to as asbestos and semi-metallic (or "semi-met") friction materials, respectively. Asbestos friction materials typically lose friction coefficient upon being burnished. Semi-metallic friction materials typically gain friction coefficient upon being burnished. (See Appendix 10, Brake Burnish). The effect of these changes in friction coefficients on brake system output or specific torque will be a function of brake design and type.

Tires have been found to increase in peak traction capability upon undergoing burnish (see Appendix 11, Tire Burnish). Typically, the tires in wide use today, low rolling resistance tires of a radial ply construction with composition, tread design and depth optimized for wet, dry, and snow traction, wear, noise, and fuel economy, have an initial peak traction coefficient as low as 0.7, which is anywhere from 12% to 22% lower than the same tires have after they are burnished. This real world limit on tire peak traction increases the difficulty in complying with a stringent pre-burnished effectiveness requirement, because it reduces the stopping ability of even the most effective brake system.

The stringent stopping distance requirements for tests performed with the vehicle in the laden or GVWR condition effectively require the vehicle to be designed as close as possible to the ideal brake balance line in this heavily loaded condition. Therefore, because the unladen vehicle is usually more rear biased than the laden vehicle, the same vehicle in the same unburnished brake and tire condition will have to be rear biased in the lightly loaded or driver only loading condition. By virtue of being further away from the ideal line, the brake balance in the unladen condition results in longer stopping distances unladen than laden.

Experience with the preburnish requirements of FMVSS 105 is indicative of how the proposed regulation will affect brake performance. The combined requirements of FMVSS 105 fade and recovery procedures have virtually forced manufacturers to use semi-metallic friction materials on the front disc brakes of vehicles. The short stopping distance requirement of the FMVSS 105 first effectiveness forces the manufacturer to employ a rear brake design with high output in that green brake condition to make up for the semi-metallic friction materials on the front disc brakes, with their typically 40% lower output in the unburnished condition. The customer is best served by a vehicle with the shortest stopping distance in the <u>burnished</u> brake condition. Consequently, the designer (who has some control on amount of change in rear brake output by rear brake design selection) depends upon rear brake designs that experience a large reduction in output as they burnish, so that rear brake output will be fully what the designer intended after the fronts are properly burnished. Employment of rear brake designs producing a smaller green to burnished reduction would force the manufacturer to accept longer burnished stopping distances, i.e. smaller pass margins, in subsequent portions of the 105 test procedure, and thereby increases the risk of producing a noncomplying vehicle. Thus, a dilemma exists for the manufacturer which is the singular consequence of the realities of real world tires and friction materials and the requirements of FMVSS 105.

Fortunately, consideration of a new harmonized brake standard offers an opportunity to pursue an alternate approach that would eliminate the above dilemma; simply eliminate any pre-burnished requirement from the proposed US standard. This approach would offer at least two immediate advantages. By eliminating the green brake requirement altogether the NHTSA would bring the proposed US requirement into agreement with the harmonized draft proposal R.88 and thereby increase the probability of a truly worldwide braking standard. Secondly, the manufacturer would then be free to optimize the brake system performance in the burnished condition without having the design driven by the short lived green brake and tire condition.

To illustrate the benefits of eliminating a green brake effectiveness requirement from the proposed US standard, an analysis has been made based on GM vehicle tests and the theoretical example vehicle being used for this response. Two rear brake designs have been considered. The first is a drum brake design that experiences a 10% reduction in output by burnishing, the second is a drum brake design that experiences a 30% reduction in output due to burnish. Both rear brakes are assumed to have a burnished specific torque of 0.40 ft-lb/psi (0.079 N-m/kPa). The drum brake design producing the 10% reduction in output due to burnish is representative of vehicles built to meet ECE R13 (which has no preburnish requirement), and is called, for identification in this discussion, the "ECE R13" design. The drum brake design producing a 30% reduction in output due to burnish is representative of a vehicle designed to meet FMVSS 105, and is identified as the "105" design. The front brakes are assumed to be semi-metallic friction element disc brakes that undergo a 40% increase in specific torque with burnish. Since disc brake output is linearly dependent upon friction coefficient, little can be done to reduce their sensitivity to friction coefficient changes, and no alternate designs were assumed. The front brakes were assumed to have a burnished specific torque of 0.80 ft-lb/psi (0.157 N-m/kPa).

To demonstrate that the stringent stopping distance requirement of the 1st effectiveness portion of FMVSS 105 encourages the use of the 105 design rear drum brake, consider figure 1. Here, the normalized braking efficiency of the example vehicle in the GVW or laden condition is plotted for the green brake and tire condition with either the ECE R13 rear brake design or the 105 rear drum design. (Note that the normalized brake efficiency line curve for the ECE R13 type design is lower than the the 105 type line. Remember that as the brakes burnish the rears will decrease in output, forcing the system to be more front biased. Since ECE R13 precludes rear bias in the burnished condition, this green brake condition must be sufficiently below the neutral balance line to allow room for the balance change to still be front biased.) On the assumed 0.70 peak coefficient green tire, the vehicle configuration employing the ECE R13 rear brake design locks its front wheels at a deceleration of 0.62g (6.08 m/sec^2, 20 ft/s^2; line "a" on figure 1). The vehicle configuration employing the 105 rear brake design configuration also locks its front wheels but at a deceleration of 0.67g (6.57 m/sec^2, 21.6 ft/s^2; line "b"). Assuming a system reaction time of 0.60 seconds, these decelerations translate into minimum stopping distances of 220.5 ft (67.2 m) for the ECE R13 drum brake car, and 206.0 ft (62.8 m) for the 105 drum brake configuration for tests run from 60 mph (96.6 km/h). Thus, a difference of 14.5 ft (4.4 m) in stopping distance is produced by employing the design incorporating the larger output change. It should be pointed out that the ECE R13 drum brake configured vehicle would fail the 1st effectiveness requirement of FMVSS 105 for a 60 mph (96.6 km/h) test speed, and the 105 drum brake configured vehicle would pass the requirement which allows a maximum stopping distance of 214 ft (65.2 m) from 60 mph (96.6 km/h). This illustration hopefully makes it clear that the stringent pre-burnished (1st eff) requirement of FMVSS 105 forces the use of the rear brake design incorporating large coefficient change during burnish (the "105" design) rather than the design that results in less coefficient change (the "ECE R13" design). Elimination of the pre-burnished effectiveness requirement would allow brake designs with greater consistency from new to burnished.

An interesting related observation is that a green brake and tire effectiveness test performed at the lightly loaded condition would encourage the manufacturer to employ the ECE R13 design rather than the 105 rear brake design. This point is illustrated by considering figure 2 where the normalized brake efficiency at first axle lock for our example vehicle is plotted in the lightly loaded vehicle condition using both the assumed ECE R13 and 105 rear brake designs. In this loading condition, the vehicle equipped with the ECE R13 rear brake locks its rear axle first at a deceleration of 0.60g (5.88 m/sec^2, 19.3 ft/sec^2; line "c") on the 0.70 peak coefficient tire, and the vehicle equipped with the 105 rear brake and the same tire locks its rear axle at a deceleration of 0.51g (5.00 m/sec^2, 16.4 ft/sec^2; line "d"). These decelerations translate into minimum stopping distances from 60 mph (96.6 km/h) with the same system 0.60 sec reaction time of 262.36 ft (80 m) for the 105 rear brake equipped vehicle and 226.98 ft (69.2 m) for the ECE R13 equipped vehicle. Thus, by testing the green brake and tire performance in the unladen condition, the manufacturer is encouraged to use and further develop rear brake designs that produce smaller changes in output due to the inevitable friction coefficient changes produced in the lining due to burnish.

The stopping distances cited above are true theoretical minimums, and do not recognize any corrections for inevitable side to side torque variations, side to side variations in tire traction limits, nor provide any pass margin for the manufacturer to allow some assurance of 100% vehicle compliance, as required under self certification. In the green brake condition, GM test data indicates as much as a 40% side to side torque variation is not unusual during the first few stops on the vehicle. Because new vehicles delivered to the customer have inevitably experienced a few stops during the driving of the vehicle out of the manufacturing plant and onto the transport vehicle, and usually a few stops during delivery at the dealership, tests of truly green brakes and tires represent an absolute worst case.

To illustrate a reasonable method of establishing stopping distance requirements that are consistent with the laws of physics, a series of example calculations for the pre-burnished effectiveness requirement have been prepared. These calculations are intended to demonstrate methodology for establishment of minimum stopping distances, and may not represent the final GM position on the issue since the agency has not firmly established the entire set of procedural requirements that might be included in the final US proposal for a harmonized braking standard.

In order to comprehend a manageable number of the possible permutations of test requirements and limitations on the vehicle that might become part of the final standard, two possible scenarios were considered. It was assumed that with regard to the adhesion utilization requirement, the agency would either adopt the European approach to design compliance by calculation, or the agency would adopt a strict vehicle test requirement. (The adoption of an adhesion utilization requirement with a specific vehicle test which allows reasonable tolerances can be considered to be equivalent to the European calculation approach.) Likewise, the analysis presented here assumes no side to side torque, tire peak traction, or weight variation in the test condition.

To illustrate the methodology, consider figure 3. Here the vehicle equipped with the "105" rear brake design is plotted as normalized brake efficiency at first axle lock, both unladen (upper curve) and laden (lower curve). Recall, this is the brake configuration encouraged by a pre-burnished effectiveness requirement that is established for the laden vehicle condition. Further, the vehicle decelerations at first axle lock on a 0.70 green tire are identified as 0.51g (16.4 ft/s^2, 5.0 m/s^2) for the unladen condition and 0.67g (21.6 ft/s^2, 6.6 m/s^2) in the laden condition. These decelerations convert to 100 km/h (62.1 mph) stopping distances of 275.4 and 219.9 feet (83.9 and 67 m) assuming a system reaction time of 0.60 seconds. A similar plot of normalized brake efficiency at first axle lock for the same example vehicle in the laden and unladen conditions equipped with the ECE R13 rear brake is shown in figure 4. Here, the vehicle deceleration capability on a green, 0.70 peak coefficient tire is 0.60g (19.3 ft/s^2, 5.9 m/s^2) for the unladen condition and 0.62g (20 ft/s^2, 6.1 m/s^2) in the laden condition. These decelerations convert to 100 km/h (62.1 mph) stopping distances of 242.3 and 235.4 feet (73.9 and 71.8 m) respectively. These distances represent absolute theoretical minimum estimates, and would not allow any pass margin to the manufacturer.

Similar plots for the example vehicle designed to comply with a strict specific vehicle test in both the laden and unladen conditions are shown in figures 5 and 6. (Remember, the vehicle will become less rear biased with burnish so when viewing figure 5 consider that the upper, unladen, line will drop below the 100% efficiency line to the front biased region.) The theoretical maximum deceleration at first axle lock is identified on each plot for the vehicle operating on the 0.70 peak coefficient green tire. The overall calculation of theoretical minimum stopping distances and a GM recommended stopping distance requirement to provide a minimum 10% pass margin are shown in table 1.

These calculated stopping distances are by no means the final word on this issue, but clearly illustrate the methodology recommended by GM. Properly accounting for the inevitable real world factors described earlier, such as side to side torque, or tire peak traction variations, would increase the estimates of minimum stopping distance and the GM recommended allowable stopping distances to provide a reasonable pass margin for the manufacturer.

The final point to be made is that a casual review of table 1 might suggest that the inclusion of a strict individual vehicle test for adhesion utilization might offer the advantage of reducing the required stopping distance for a pre-burnished effectiveness requirement. While it is true that forcing a manufacturer to design large degrees of front bias into the burnished brake system performance at all vehicle loading conditions will allow shorter stopping distances in the first few stops of a vehicle's lifetime, longer stopping distances are produced by this brake balance in the burnished condition, particularly in the laden condition. To sacrifice stopping distance in the burnished brake condition simply in order to reduce green brake and tire stopping distances seems contrary to the purpose of vehicle safety. More detailed discussion of this subject will be offered in Appendix 17, Burnished Brake Performance.

FIG 1. EXAMPLE VEHICLE, GREEN BRAKES, LADEN

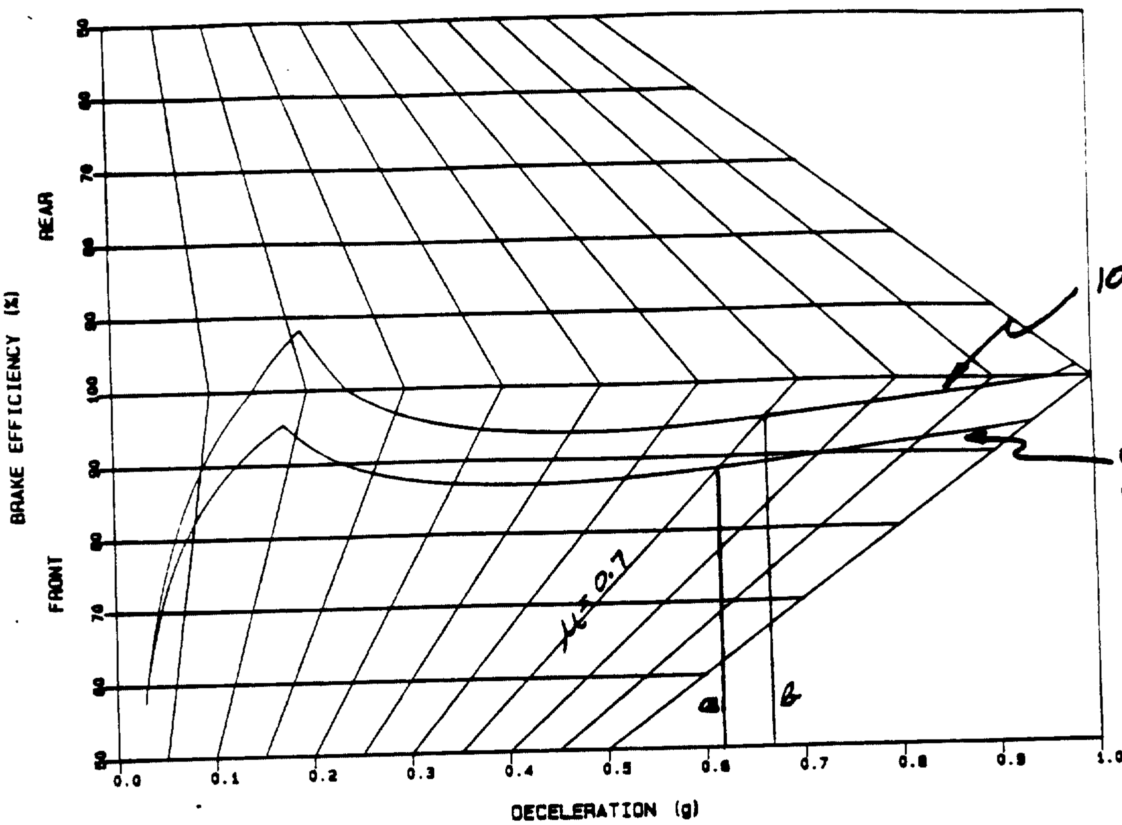
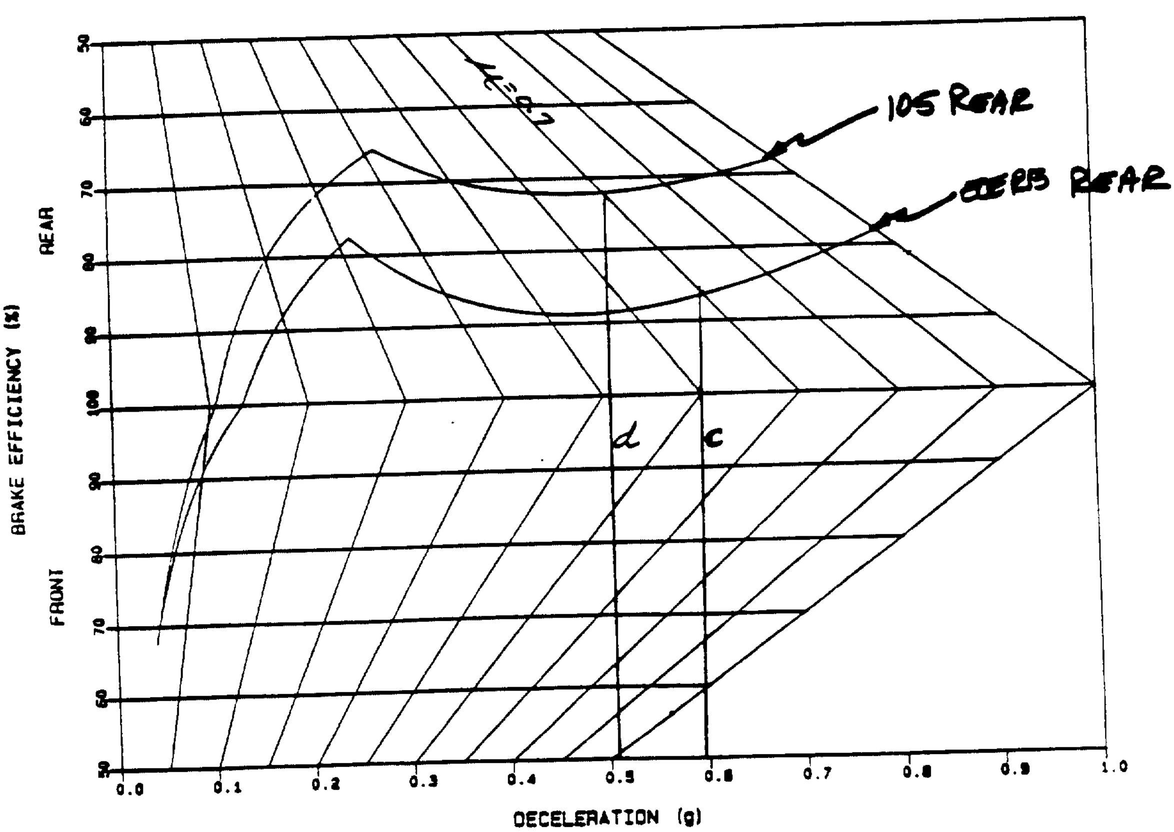
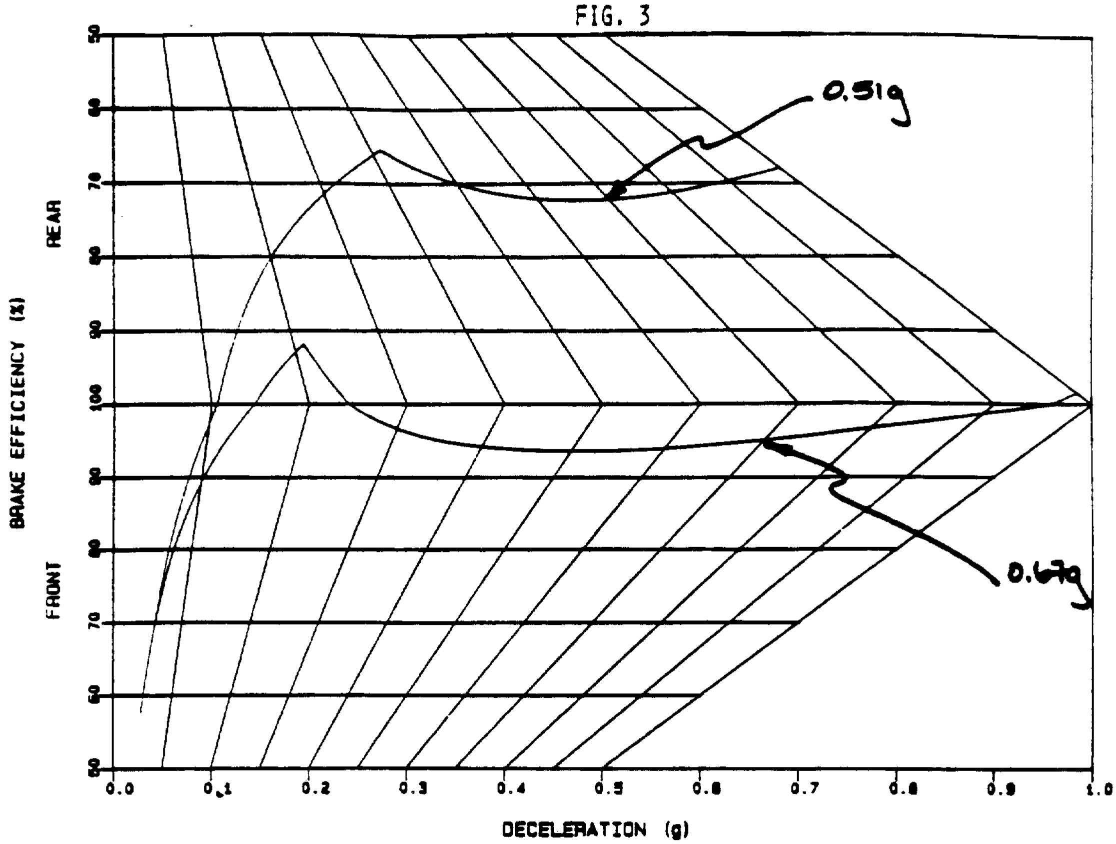


FIG 2. EXAMPLE VEHICLE, GREEN BRAKES, UNLADEN



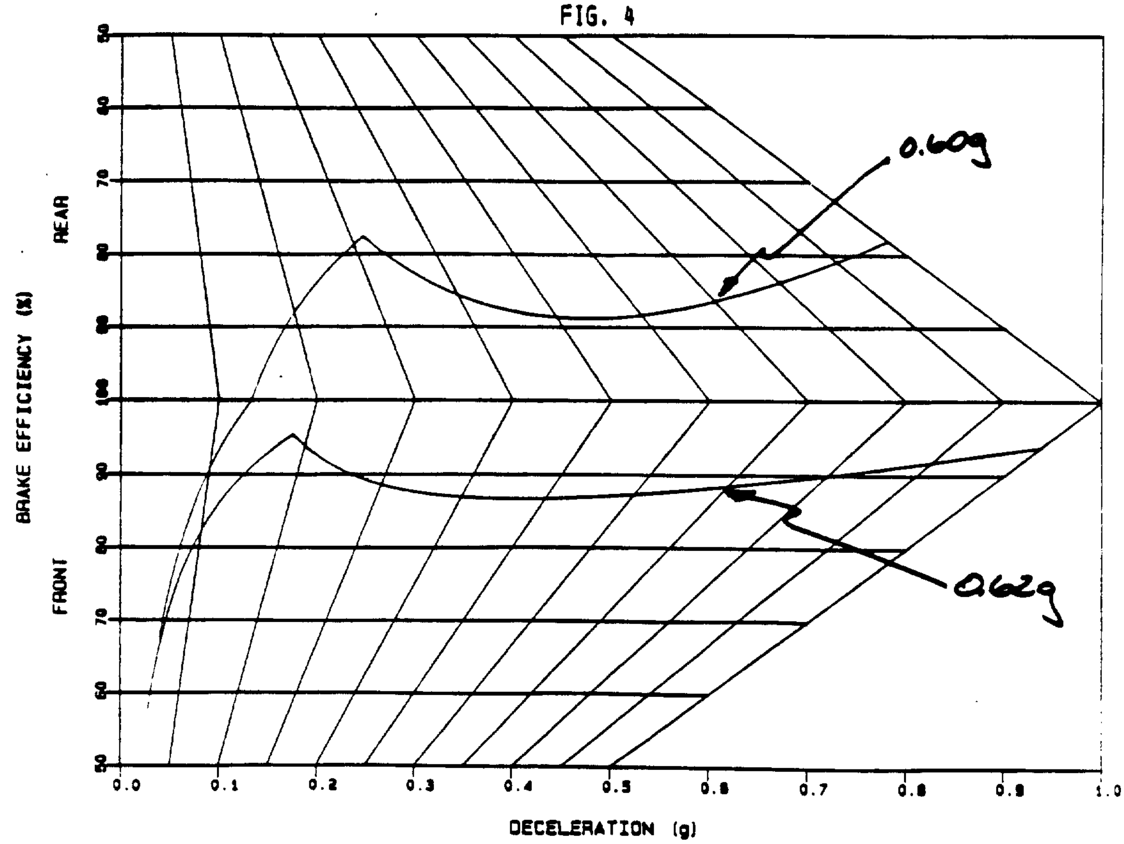
EX VECH, W/O TEST, GREEN BRAKES, 105 REAR

FIG. 3



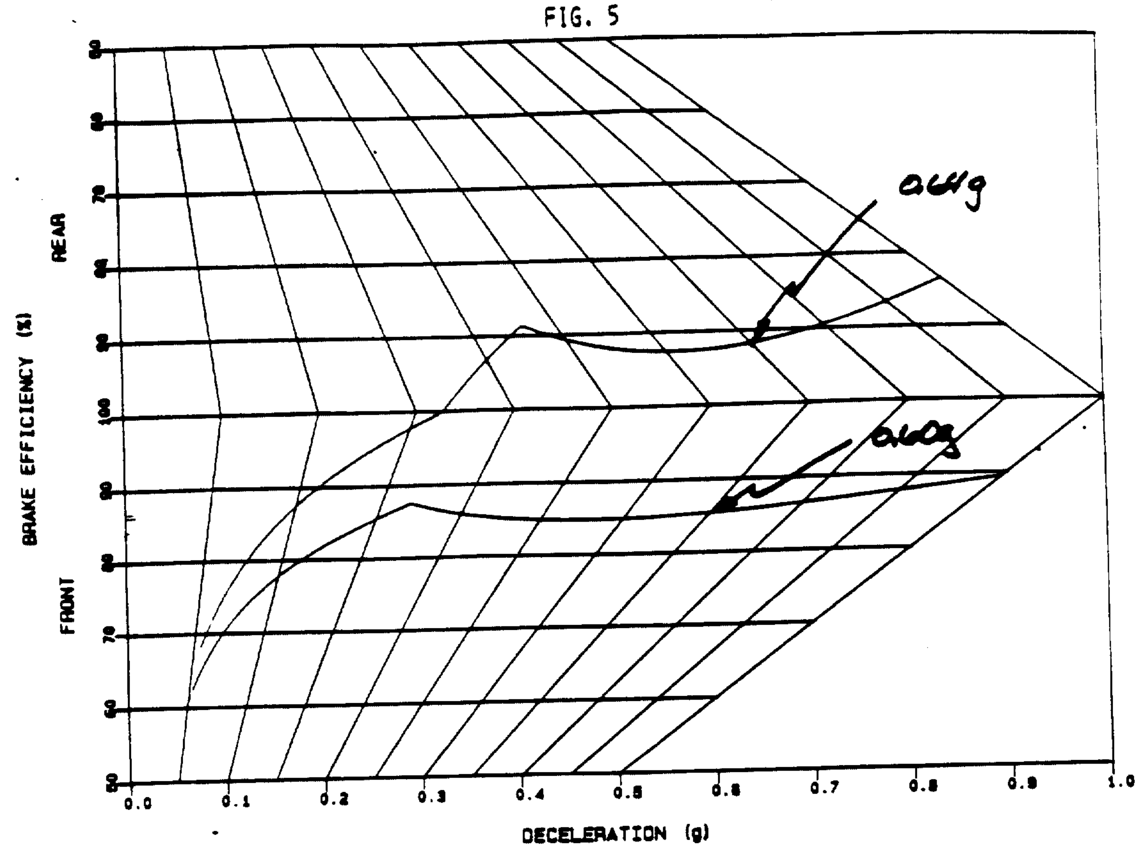
EX VECH, W/O TEST, GREEN BRAKES, EEC REAR

FIG. 4



EX VECH, WITH TEST, GREEN BRAKES, 105 REAR

FIG. 5



EX VECH, WITH TEST, GREEN BRAKES, EEC13 REAR

FIG. 6

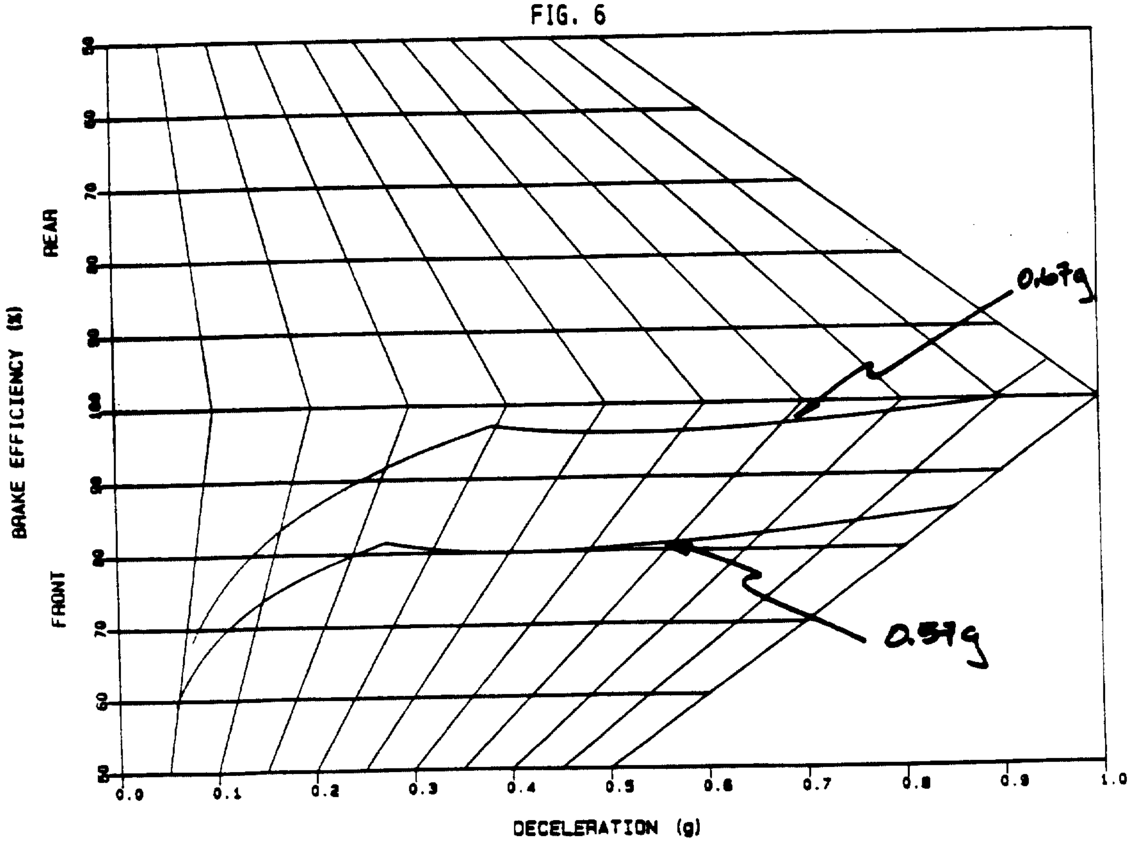


TABLE 1. EXAMPLE VEHICLE PRE-BURNISHED EFFECTIVENESS

100 Km/h STOPPING DISTANCES (0.70 μ peak) (GREEN BRAKES)

Adhesion Test	Loading	Bias	Decel, g	Decel, m/sec^2	*min SD		*10% Pass SD	
					Feet	Meters	Feet	Meters
W/O Test	LLV	Rear	0.60	5.88	242.3	73.9	266.6	81.3
ECE Rear	GVW	Front	0.62	6.08	235.4	71.8	259.0	78.9
W/O Test	LLV	Rear	0.51	5.00	275.4	83.9	303.0	92.4
105 Rear	GVW	Front	0.67	6.57	219.9	67.0	241.9	73.7
With Test	LLV	Front	0.67	6.57	219.9	67.0	241.9	73.7
ECE Rear	GVW	Front	0.57	5.59	249.8	76.1	274.7	83.7
With Test	LLV	Rear	0.64	6.28	228.9	69.8	251.8	76.7
105 Rear	GVW	Front	0.60	5.88	242.3	73.9	266.6	81.3

*These calculations assume no pedal force limit is achieved, no side to side torque or weight variation, 0.70 μ peak tires front & rear, 0.60 sec system reaction time, and rigid body inertial force transfer.

FMVSS 135 ALLOWS 236 FT

BURNISHED BRAKE PERFORMANCE
(Cold Effectiveness)

OBJECTIVE

The purpose of this appendix is to establish the absolute theoretical minimum burnished (cold effectiveness) stopping distance for two nominal example vehicles (one front wheel drive (FWD) and the other rear wheel drive (RWD)) in laden and unladen loading conditions for any given tire to road coefficient. The methodology is applied to two versions of both the FWD and RWD example vehicles, one considering a calculation approach to brake balance regulation, and the other considering a strict vehicle test.

CONCLUSIONS

1. Theoretical minimum burnished stopping distances for both FWD and RWD example vehicles exceed the 65 m (214 ft) allowed in FMVSS 135 when a specific vehicle test of adhesion utilization is required. The FWD example even fails the 65 m (214 ft) requirement when brake balance compliance is by calculation.

2. The stopping distance proposed in R.88, (77 m, 252.6 ft) would be achievable for the example vehicles analyzed if brake balance compliance is by calculation. If balance is by specific vehicle test, the FWD vehicle would have less than a 10% pass margin to the 77 m (252.6 ft) proposed requirement.

RECOMMENDATIONS

1. The cold (burnished) effectiveness stopping distance must be lengthened in order to achieve a viable standard.

2. Brake balance requirement compliance should be through calculation, as is used in ECE R13.

DISCUSSION

Methodology has been developed to establish the absolute theoretical minimum stopping distance for the nominal example vehicle in laden and unladen loading conditions for any given tire to road coefficient. No attempt to include variability effects is made here (see Appendix 12, Variability). In the discussion which follows, this methodology is applied to two versions of both the FWD and RWD example vehicles. The first version is based on the assumption that the agency will accept an adhesion utilization certification by calculation (or the assumed equivalent specific vehicle test with appropriate tolerances) while the second version is based on the assumption that the agency will require a specific vehicle test of brake balance. These two versions of the vehicles are then analyzed to obtain both theoretical minimum and 10% pass margin stopping distances for laden and unladen loading conditions.

The theoretical minimum stopping distance of any given vehicle can be estimated from the brake balance on any given tire to road coefficient. For purposes of this response, the analytical methodology is based on several assumptions. These include the assumptions that no pedal force limits are encountered, that no side to side torque, weight, or tire traction variations are encountered, that the driver is able to decelerate the vehicle at the limit of adhesion on the limiting axle, and that the system reaction time is 0.60 seconds (discussed in Appendix 9, Brake System Reaction Time). The theoretical minimum stopping distances of the nominal vehicles are estimated here based on a tire peak traction coefficient of 0.80. This value is based on extensive GM testing of tires in the burnished condition, as discussed in Appendix 11, Tire Burnish.

In Appendix 16, Pre-burnished Brake Effectiveness, it was assumed that the FWD example vehicle was equipped with one of two distinct rear brake designs; either a rear brake encouraged by compliance with FMVSS 105 or a rear brake encouraged by compliance with ECE R13. In either case, the burnished output of these two rear brake designs was 0.40 ft-lb/psi (0.079 N-m/kPa). That output value will be used for each brake design for the following discussion of burnished brake performance.

Since both example vehicles are front axle limited in all loading conditions regardless of the method of demonstrating compliance to adhesion utilization, the limiting deceleration rate of the vehicle is given by equation (15) in Appendix 2,

$$A = (ub)/\{[(a+b)(1-R)]-(uh)\}$$

where the symbols are as defined in that Appendix. For the FWD example vehicle designed to meet the adhesion utilization requirement of FMVSS 135 by calculation (without test), the maximum deceleration of the vehicle in the unladen condition is given by substituting into the above equation to yield a value of 0.79g (25.4 ft/s^2, 7.7 m/s^2). This value is confirmed by examining the plot of normalized brake efficiency at first axle lock for both the laden and unladen vehicle, as shown in figure 1. Here, the vehicle is balanced very close to the ideal line in the lightly loaded condition, and therefore can achieve the relatively high deceleration rate of 0.79g (25.4 ft/s^2, 7.74 m/s^2) on a 0.80 tire to road coefficient (line "a"). Assuming a brake system reaction time of 0.60 seconds, this deceleration rate translates into a theoretical minimum stopping distance of the average vehicle in this configuration of 190.6 feet (58.1 m) and a 10% pass margin stopping distance of 209.7 feet (63.9 m), both calculated for a vehicle initial speed of 100 km/h (62.1 mph).

In the laden condition, the same vehicle on a 0.80 coefficient can achieve a deceleration of 0.67g (21.6 ft/s^2, 6.54 m/sec^2), as shown in figure 1, line b. This deceleration rate translates into a theoretical minimum stopping distance of 219.8 feet (67 m) from a speed of 100 km/h (62.1 mph). Thus, in the laden condition, this vehicle fails to meet the requirements of FMVSS 135 or 214 feet (65 m). Keep in mind this is based on the absolute theoretical minimum stopping distance and neglects any of many other factors that will only increase the stopping distance.

To illustrate the impact of requiring a specific vehicle test to certify adhesion utilization of brake balance, the example FWD vehicle balanced to meet this type requirement is shown in both loading conditions as normalized brake efficiency at first axle lock in figure 2. In this configuration, the unladen normalized brake efficiency line has been designed further toward the front bias condition (the brake efficiency is lower on the graph) to allow for the requirement that the entire vehicle population remain front biased, or below the 100% efficiency line. Here, the unladen vehicle on a 0.80 surface is theoretically capable of a deceleration of 0.75g, 24.2 ft/s^2, 7.35 m/s^2; line c). From a vehicle initial speed of 100 km/h (62.1 mph), and with a brake system reaction time of 0.60 seconds, this deceleration translates into a theoretical minimum stopping distance of 199.3 feet (60.7 m) and a 10% pass margin distance of 219.3 feet (66.8 m). The laden vehicle on the same tire to road coefficient can achieve a theoretical maximum deceleration of 0.62g (20 ft/s^2, 6.08 m/s^2; line "d"). From 100 km/h (62.1 mph) and the same reaction time, this translates into an absolute minimum stopping distance of 235.4 feet (71.8 m) and a 10% pass margin distance of 258.9 feet (78.9 m). Again, the vehicle fails to meet the proposed requirements of FMVSS 135 in either the laden or the unladen condition.

Similar analysis can be made on the example RWD vehicle, as shown in figures 3 and 4. The complete results of all versions of both the FWD and RWD vehicles, with and without a specific vehicle test for adhesion utilization, are shown in table 1.

TABLE 1. THEORETICAL MINIMUM STOPPING DISTANCE FROM 100 km/hr

[FMVSS 135 proposed to allow 65 m (214 ft)]

VEHICLE	LOADING	DECEL,g	DECEL	MIN DIST	10% PASS
FWD W/O TEST	LLV	0.79	25.44 f/s^2	190.6 ft	209.7 ft
			7.74 m/s^2	58.1 m	63.9 m
	GVW	0.67	21.57	219.8 ft	241.9 ft
			6.57	67.0 m	73.7 m
FWD W/TEST	LLV	0.75	24.15	199.3 ft	219.3 ft
			7.35	60.7 m	66.8 m
	GVW	0.62	19.96	235.4 ft	258.9 ft
			6.08	71.8 m	78.9 m
RWD W/O TEST	LLV	0.79	25.44	190.6 ft	209.7 ft
			7.74	58.1 m	63.9 m
	GVW	0.70	22.54	211.6 ft	232.8 ft
			6.86	64.5 m	71.0 m
RWD W/TEST	LLV	0.75	24.15	199.3 ft	219.3 ft
			7.35	60.7 m	66.8 m
	GVW	0.66	21.25	222.8 ft	245.1 ft
			6.47	67.9 m	74.7 m

The 10% pass margin minimum estimates given above are remarkable close to the harmonized draft R.88 requirement of 252.6 feet (77 m). The differences in theoretical minimum stopping distance indicated in table 1 clearly illustrate the implication of a vehicle test of brake balance, and the consequences such a requirement would have on stopping distance.

EX FWD VECH W/O TEST, LADEN AND UNLADEN

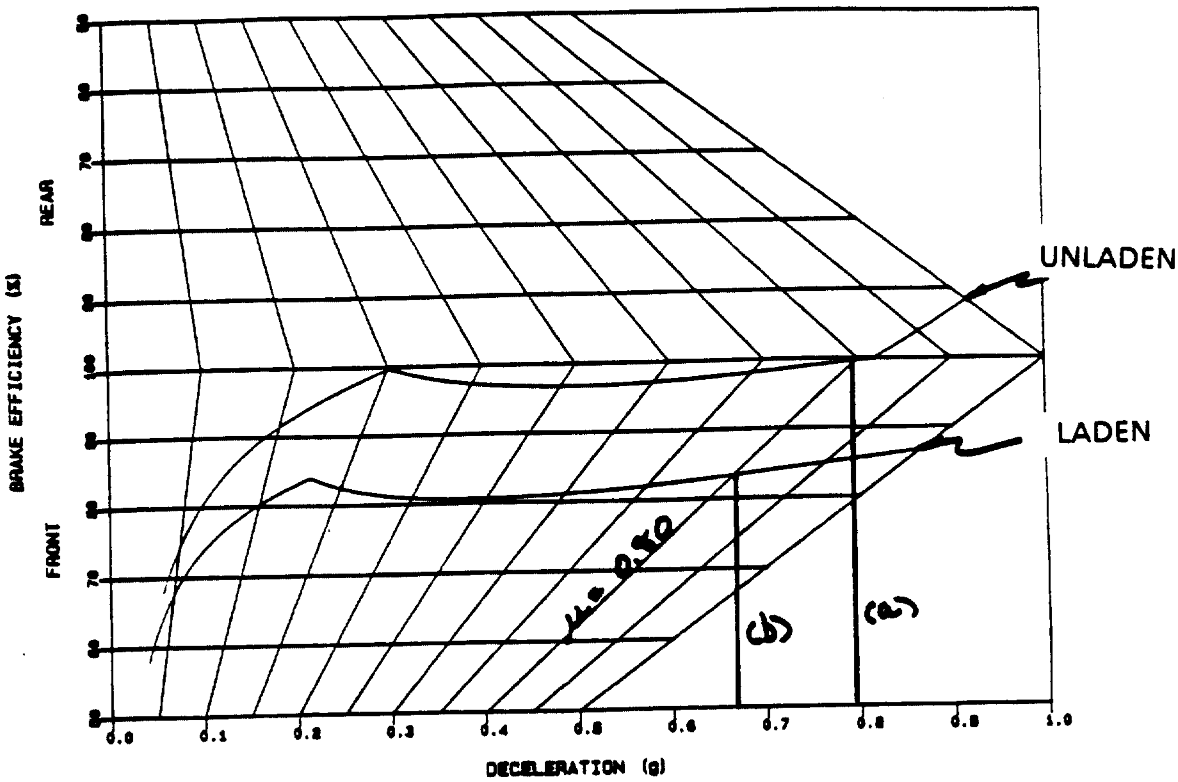


Figure 1

EX FWD VECH W/TEST, LADEN AND UNLADEN

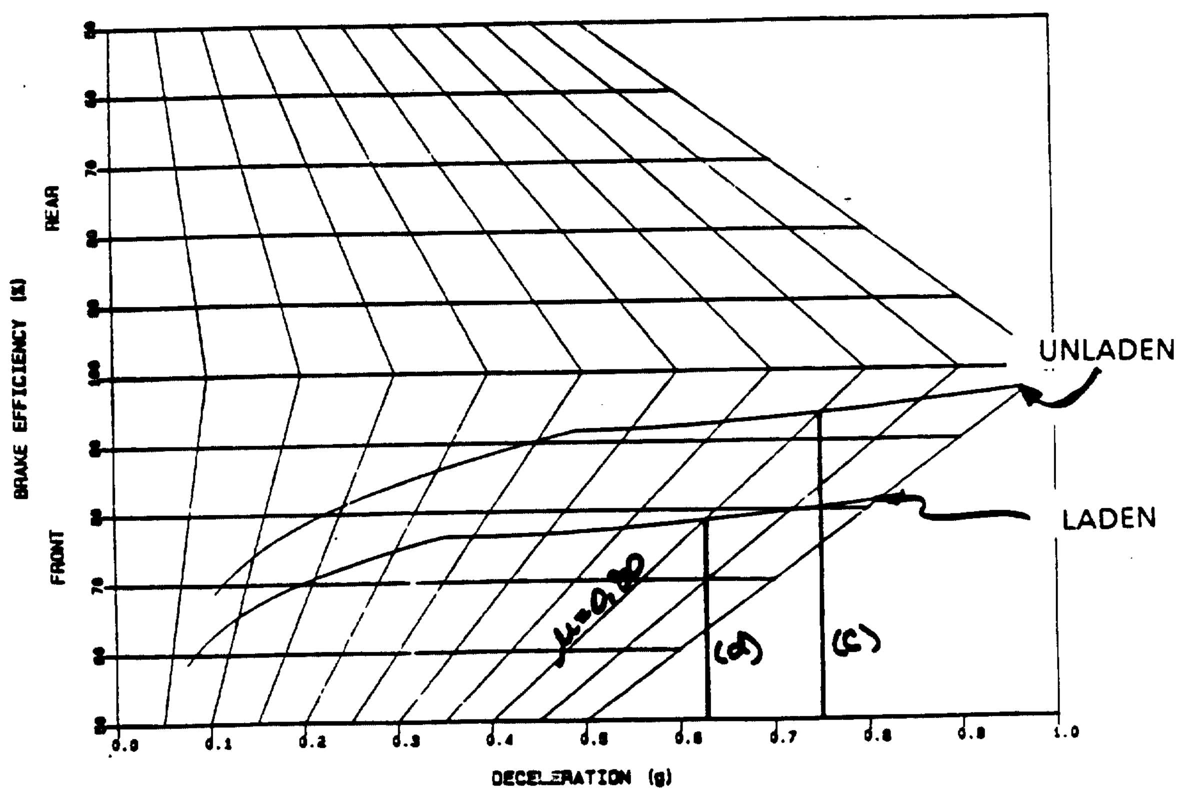


Figure 2

EX RWD VECH W/O TEST, LADEN AND UNLADEN

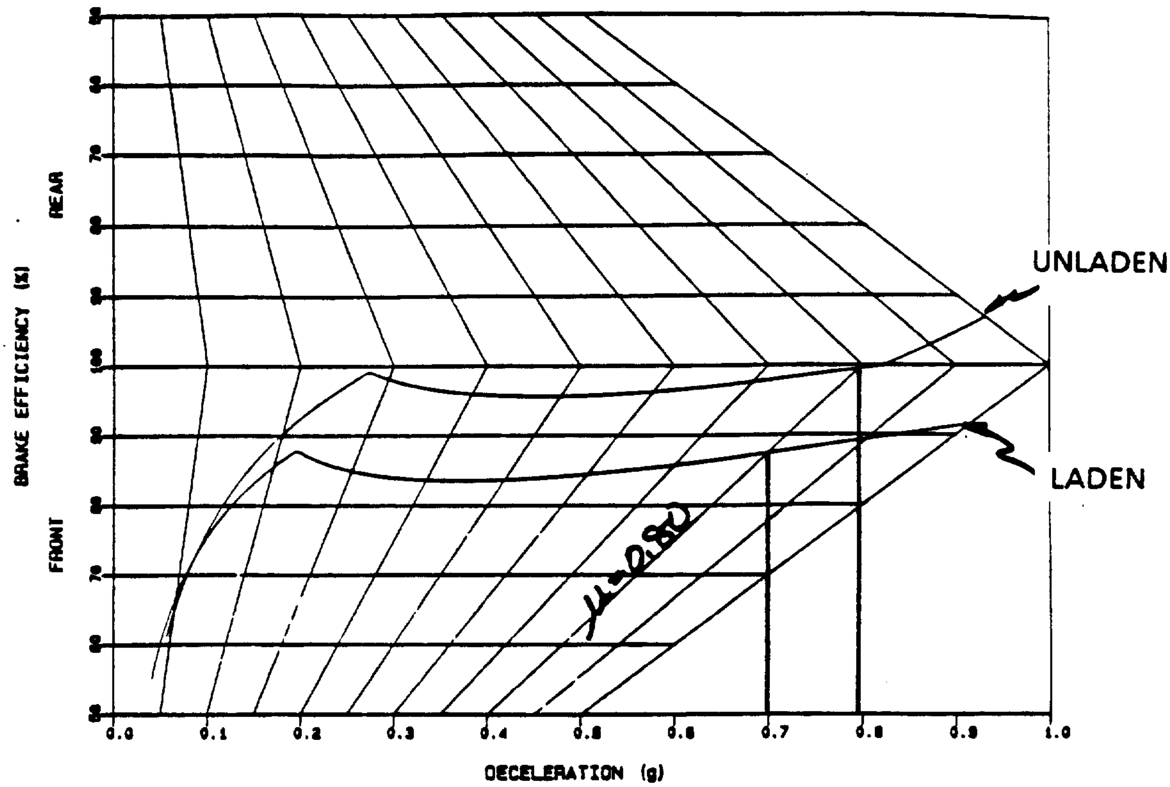


Figure 3

EX RWD VECH W/TEST, LADEN AND UNLADEN

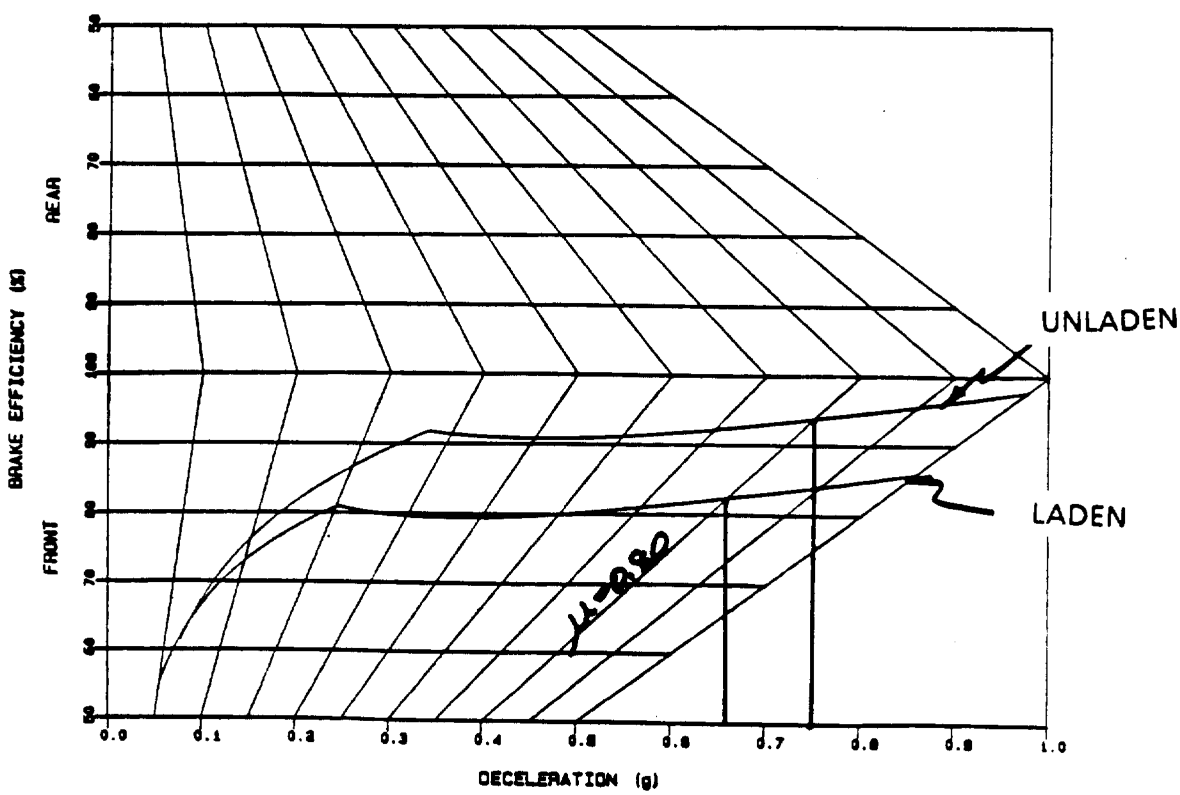


Figure 4

HIGH SPEED STOPS

OBJECTIVE

The purpose of this Appendix is to review the high speed stopping distance requirement of FMVSS 135 and to compare them to the corresponding requirement in FMVSS 105 and draft proposal R.88.

CONCLUSIONS

1. The high speed requirements in FMVSS 135 are more stringent than those in FMVSS 105, ECE R13, or draft proposal R.88.

2. The stopping distance requirements from an unbounded 80% of V_{max} present a compliance test condition with which very little experience exists, and which would appear to be unrealistic in terms of customer driving habits.

3. The stopping distance formula in FMVSS 135 for high speed performance is incorrect in terms of the allowed brake system reaction time, and requires significantly higher deceleration than that required for FMVSS 105.

4. A new stopping distance formula given by

   $$D = 0.083V + 0.007422V^2$$

   would be essentially equivalent to the current requirements for high speed stopping distances in FMVSS 105.

RECOMMENDATIONS

1. The agency should adopt a high speed stopping distance formula that includes both representative brake system reaction time

and vehicle deceleration rate terms.

2. The agency should adopt an upper bound for the required maximum test speed.

3. Until considerable additional vehicle testing can be completed which would substantiate alternate requirements, the agency should adopt the high speed provisions of R.88.

DISCUSSION

High speed tests of vehicle braking performance are an integral part of all the various standards under review in this response. While this requirement is similar in form to the high speed requirements of both R.88 and ECE R13, it differs from both in the ultimate performance levels required. The high speed performance requirements of FMVSS 105 also differ from those of FMVSS 135.

For purposes of this discussion, high speed is taken as vehicle speeds greater than 80 mph. The requirements of FMVSS 135 for high speed tests call for a vehicle operating in both the laden and unladen loading condition to stop in a distance given by the formula

$$D = 0.05V + 0.0067V^2 \qquad (1)$$

where,

D = stopping distance in meters

V = vehicle speed in km/h

The test speed V, will be 80% of V_{max} for the particular vehicle.

The first term of equation (1) is the brake system reaction time term and establishes the distance allowed for the vehicle to achieve full deceleration from the time pedal force is applied. GM has established that the reaction time (0.36 seconds) allowed in FMVSS 135 is too short. From vehicle test data, we conclude that the first term of (1) should be based on the reaction time of 0.60 seconds which equates to

$$D = 0.083V \qquad (2)$$

where D is the distance allowed for brake system reaction time. The vehicle test data and analysis leading to (2) is described in Appendix 9, Brake System Reaction Time.

The second term of equation (1) is the distance allowed once vehicle deceleration has been achieved. The value of vehicle deceleration equivalent to the deceleration distance coefficient given in (1) can be shown to be 0.59g, or 19 ft/sec^2 (5.78 m/sec^2). This required value of minimum average vehicle deceleration is higher than that required in either FMVSS 105 or draft proposal R.88.

The high speed test requirements of FMVSS 105 are established by the performance criteria contained within the fourth effectiveness requirements. During this test phase, a vehicle is evaluated at either 95 or 100 mph (152.9 or 160.9 km/h) with stopping distances of 607 or 673 feet (185 or 205 m) respectively. Assuming a 0.60 second brake system reaction time, these distances are both equivalent to an average minimum vehicle deceleration of 0.53g. This would imply that an FMVSS 105 equivalent stopping distance formula for vehicle speeds in excess of 80 mph (128 km/h) would be given by

$$D = 0.083V + 0.007422V^2 \quad (3)$$

where the symbols are defined as before. At 100 mph (160.9 km/h), (3) would permit a stopping distance of 674.5 feet (205.6 m). Comparison of (3) and (1) shows that the high speed stopping distances allowed in FMVSS 135 are shorter than those permitted by FMVSS 105 equivalent stopping distance formula. The magnitude of this increase in stringency associated with adoption of FMVSS 135 as presently drafted, is shown as a function of maximum vehicle speed in figure 1. With a vehicle maximum speed of 160 mph (257.5 km/h), the permitted stopping distance is more than 120 feet (36.6 m) shorter in FMVSS 135 than that which an FMVSS 105 equivalent formula would permit.

In R.88 the high speed stopping distance is determined by a formula given by

$$D = 0.10V + V^2/130 \quad (4)$$

$$D = 0.10V + 0.0077V^2 \quad (4a)$$

where the definition of the symbols is the same as in Equation (1). Comparing (4) with (1) shows that the high speed stopping distances permitted by FMVSS 135 are also shorter than those established by R.88. The magnitude of the difference, or reduction in high speed stopping distance incurred in FMVSS 135 relative to those in R.88 is shown in figure 2. In this case, a vehicle with a V_{max} of 160 mph (257.5 km/h) would incur more than 150 feet (45.7 m) reduction in high speed stopping distance under FMVSS 135.

ECE R13 has a high speed test procedure that calls for testing a vehicle from a speed equal to 80% of Vmax, but does not contain a specific performance requirement. The primary focus of the high speed test in ECE R13 has been described in several international meetings as one of vehicle stability during brake maneuvers. Thus, no relative stringency comparison can be made between FMVSS 135 and ECE R13.

The high speed requirements of FMVSS 105 are less demanding than those at lower vehicle speeds, in that they require smaller values of minimum average vehicle deceleration at the higher speeds. This approach recognizes that the kinetic energy dissipated in a stop is proportional to the square of the vehicle velocity, and the power dissipated increases linearly with vehicle speed. For example, increasing vehicle speed from 60 mph to 95 mph (96.6 to 152.9 km/h), a 58% increase in power dissipated in each brake would be experienced, and an increase of more than 250% in energy dissipated would be required. Thus it is unrealistic to expect that a vehicle braking from the higher speed can average the same rate of deceleration as it can when braking from a lower speed. Both the proposed FMVSS 135 and R.88 have high speed requirements written in a manner to require a constant average deceleration regardless of speed. R.88, however, is more realistic due to its lower average deceleration requirement.

Reasonably sized foundation brakes have a finite thermal capacity, and various types of friction materials may react differently to large inputs of power and energy. Further, many vehicle parameters such as wheel design, the use of air dams, foundation brake size, and distribution of brake forces between the front and rear axles may all interact to change the response of vehicle braking systems to large power and energy inputs. To examine these effects more carefully, the detailed behavior of various brake systems during the fourth effectiveness tests of FMVSS 105 run for this docket response were studied in detail.

The results for the four basic brake configurations during the fourth effectiveness tests are shown in figures 3-6. Since these are stopping distance tests, the front and rear brake gains were averaged over the entire stop to properly account for both in stop fade and in-stop gain that might result. Corrections for front and rear holdoff pressures were not made as only relative comparisons were needed. In general, we see that the front brake gain can vary as a function of speed, but not necessarily in a consistent fashion. For the RWD test vehicle, the front brake gain is generally higher with higher speeds, and the rear brake gain is lower, both of which make the laden vehicle more front axle limited and thereby decrease the deceleration capability of the vehicle. The FWD test vehicle demonstrates a similar trend in the disc/drum configuration, but the opposite trend in the disc/disc configuration. Friction materials vary in their response to both power and energy and test results shown here for a very small sample of friction material types may fail to recognize important performance differences among all types of vehicles and friction materials.

These results indicate that the anticipated trend in brake system performance must be studied more carefully to fully understand which of the many related vehicle parameters including brake size, friction material, wheel design, distribution of brake forces, cooling rates, ground height, etc., are most important. Likewise, while pedal force limits were not encountered in the GM tests at high speeds, other manufacturers products may experience such limitations, and find the high speed test requirements even more difficult. Until more testing is conducted, particularly at very high vehicle speeds (greater than 140 mph (225.3 km/h)), a complete understanding of the impact of large power and energy inputs to existing vehicle brake systems will not be achieved.

While all the preceding has discussed the relative requirements of high speed tests, the agency should keep in mind that in the U.S. market, a federally mandated speed limit of 55 mph exists on all public roads. The high speed driving experience of the

European community is substantially larger than exists here, and the minimum safety requirements for high speed testing are surely of higher priority to the Europeans than to the domestic market. Further, except for the recent work related to this rulemaking action, American experience (industry and government) in brake compliance testing is limited to 100 mph (160.9 km/h). In conclusion, the current requirements for high speed performance in FMVSS 135 are substantially more stringent than those of either FMVSS 105 or R.88, and are not justified. On this basis, GM recommends that the agency adopt the high speed requirements of R.88.

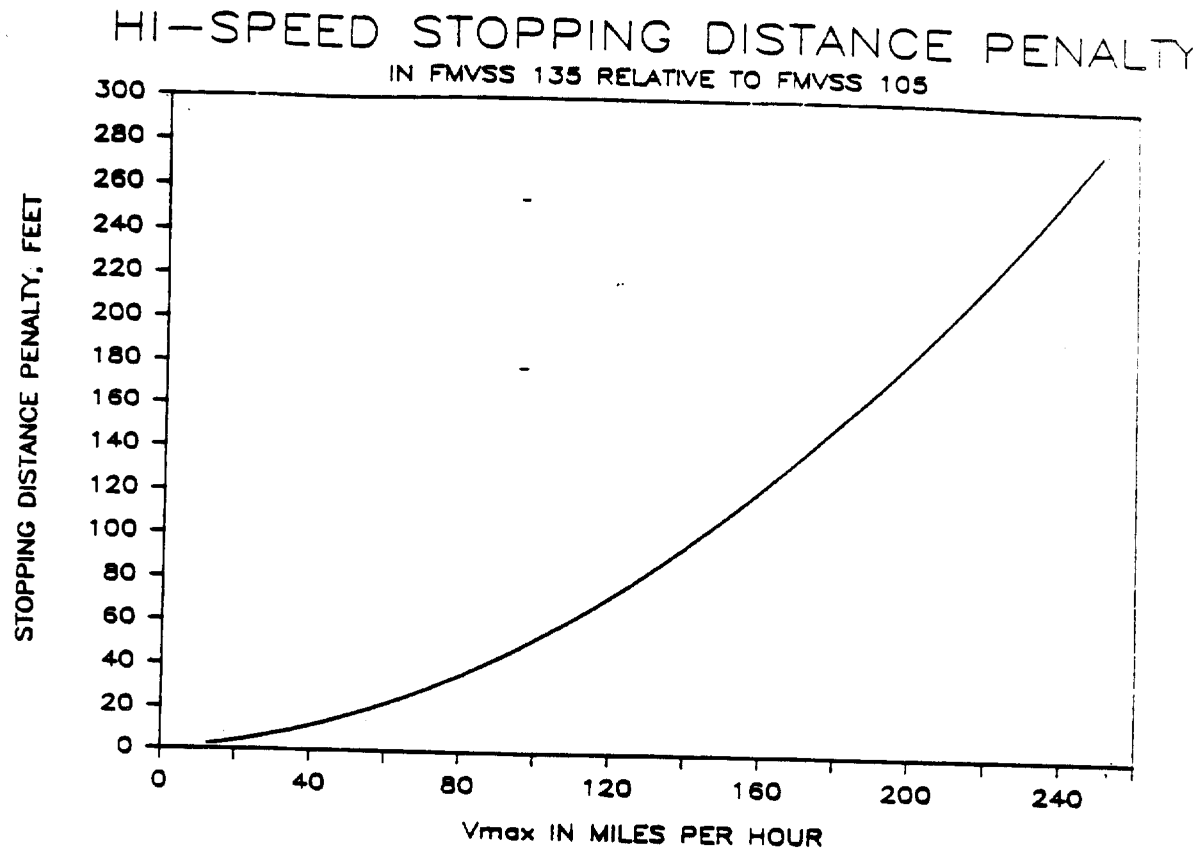


Figure 1

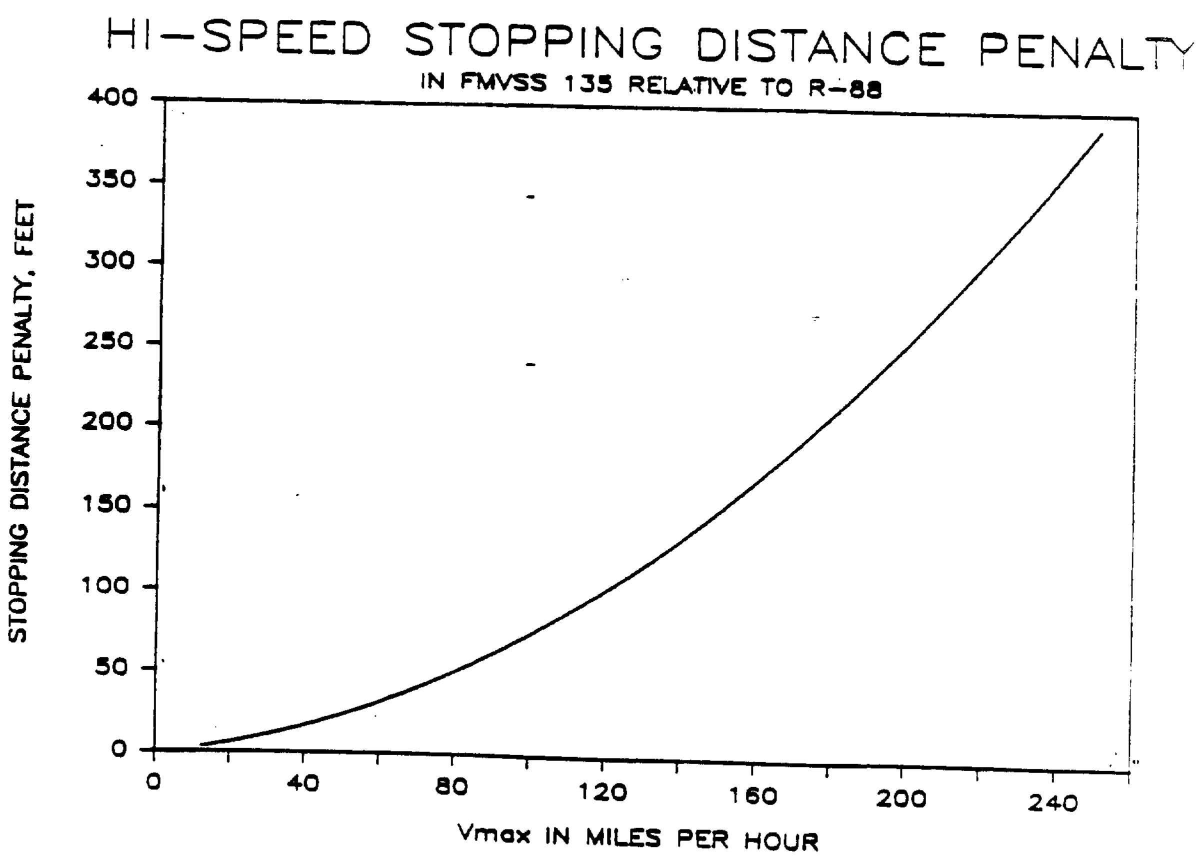


Figure 2

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Appendix 18

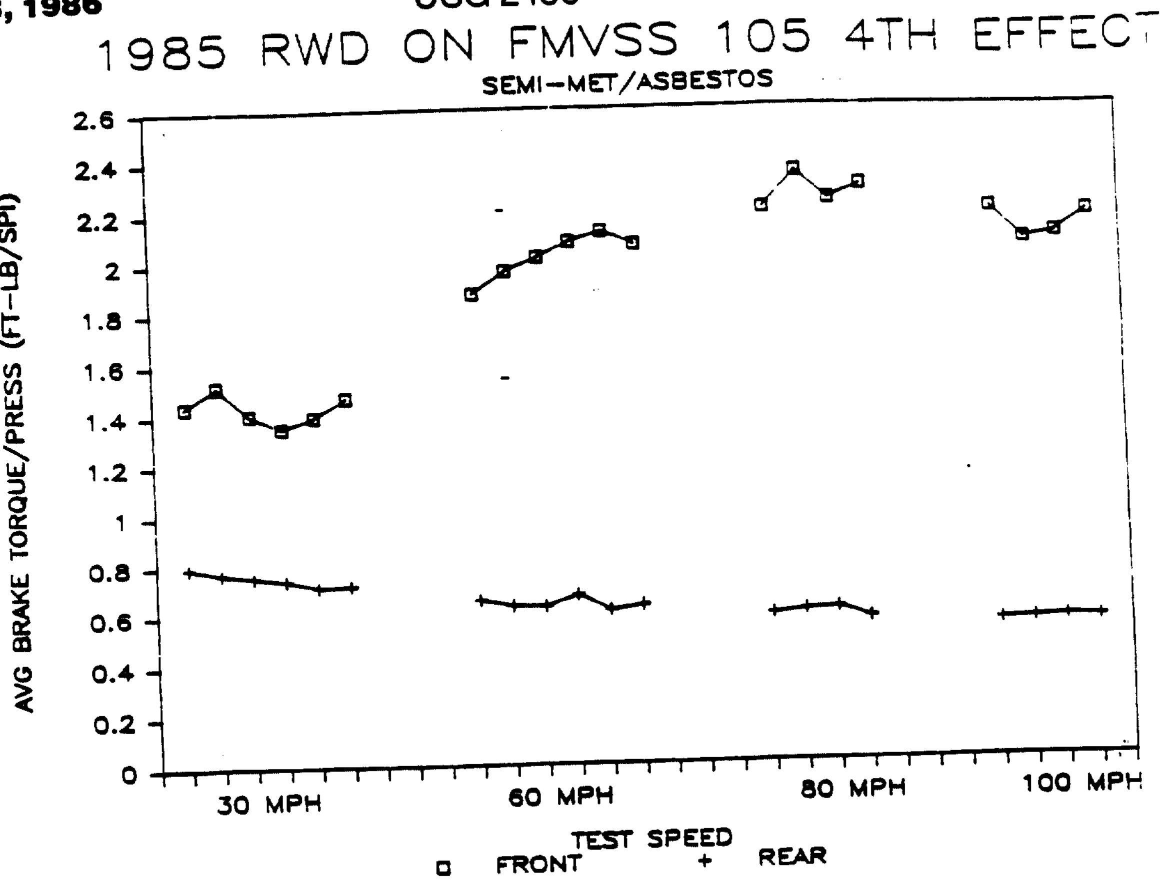


Figure 3

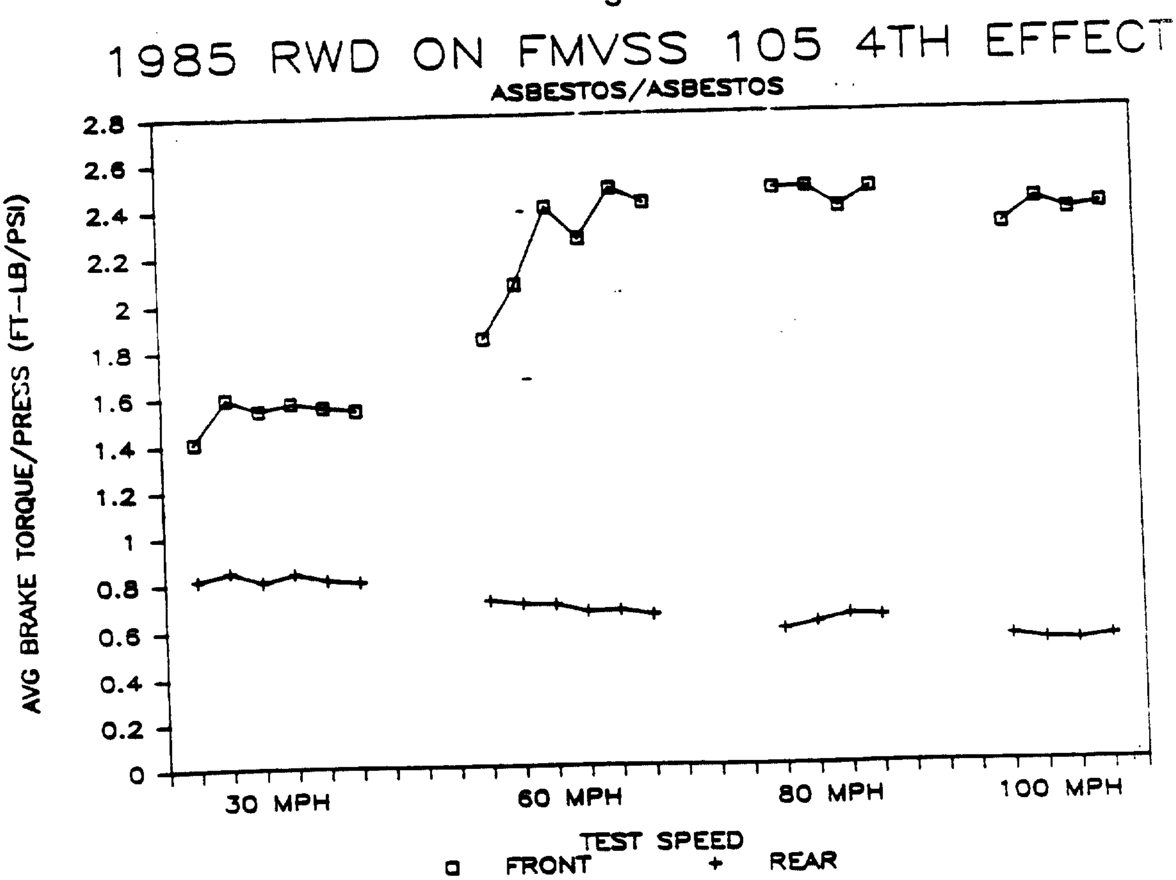


Figure 4

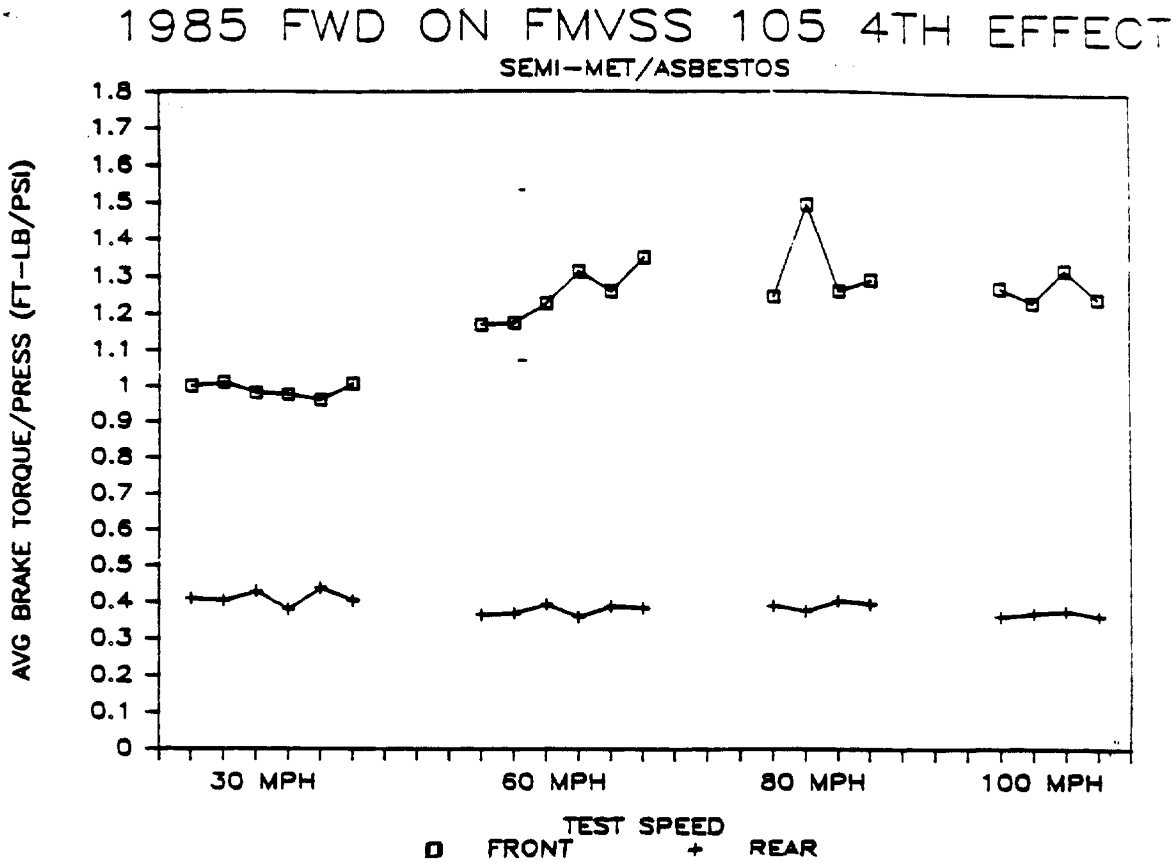


Figure 5

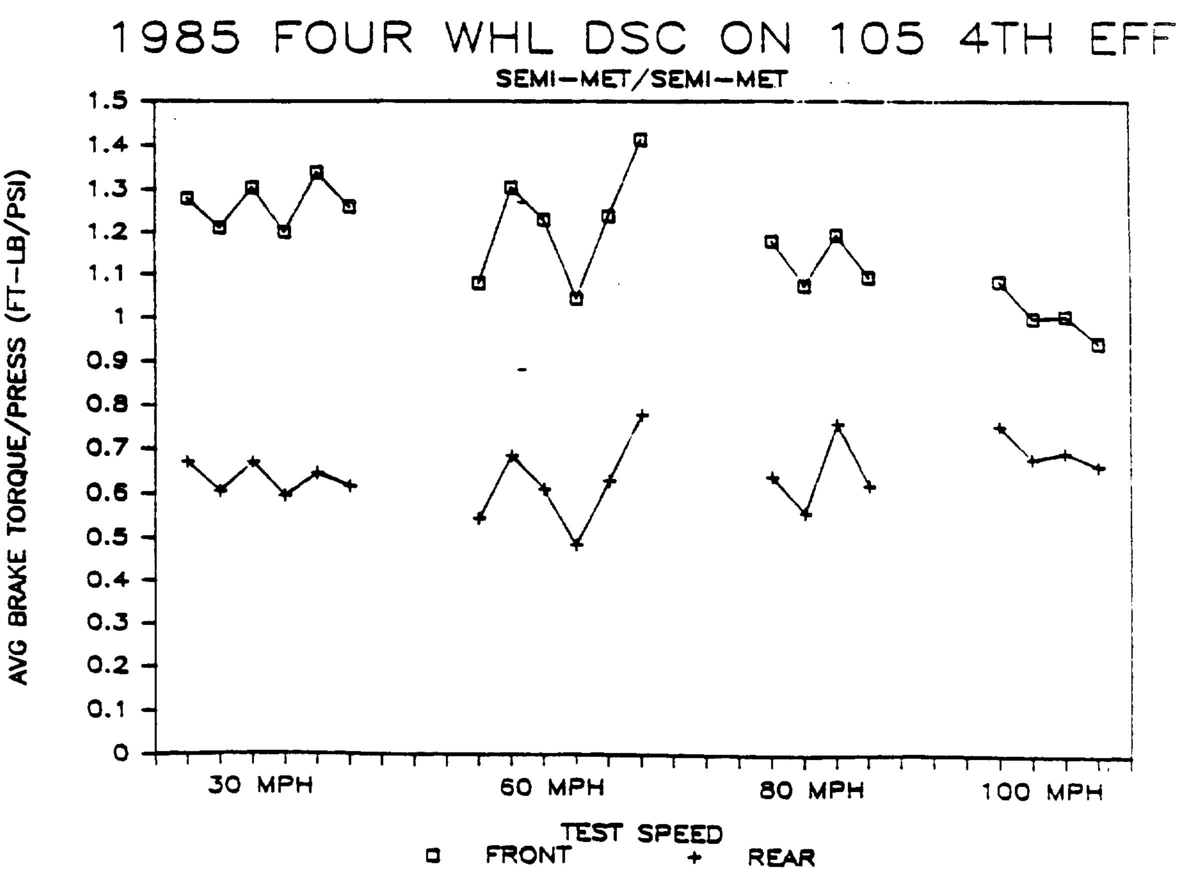


Figure 6

PARTIAL SYSTEM REQUIREMENTS

OBJECTIVE

The objectives of this Appendix are to (1) discuss the relative stringency of the partial system performance requirements of FMVSS 105, the proposed FMVSS 135 and ECE draft R.88, (2) examine the impact the proposed FMVSS 135 requirements have on rear wheel drive vehicles with front-rear partial system split designs, and (3) calculate a partial system performance requirement that appropriately recognizes both the speed and pedal force specifications and yet is equivalent to FMVSS 105.

CONCLUSIONS

1. The partial system requirements of FMVSS 135 are more stringent than those of either FMVSS 105 or R.88.

2. Front-rear split partial system designs are effectively precluded by the proposed FMVSS 135 partial system stopping distance requirements.

3. The stopping distance under the proposed FMVSS 135 test conditions that would be equivalent to FMVSS 105 and appropriately account for the increase of vehicle speed and the decrease of allowable pedal force is 614 ft (187.2 m).

RECOMMENDATIONS

In the interest of harmonization, NHTSA should adopt the partial system requirement of the proposed ECE draft R.88. This would actually be a slight increase in stringency over FMVSS 105, but the GM tests show that this level of performance is practicable.

DISCUSSION

The current partial system requirement in FMVSS 105 calls for a stopping distance of 456 feet (139 m) from 60 mph (96.5 km/h) in both the laden and unladen conditions with a pedal force limit of 150 pounds (670 N). The proposed requirement in FMVSS 135 calls for a stopping distance of 155 m (509 feet) from 100 km/hr (62.1 mph) in both the laden and unladen conditions with a pedal force limit of 500 N (112 pounds). GM tests show the proposed requirement represents a particular problem for front-rear split braking systems when tested in the rears only condition.

To understand the proposed requirements of the partial systems portion of FMVSS 135, one should consider, in particular, vehicle brake systems that are designed as front-rear splits, meaning of course that the partial system stopping distance requirements of brake standards are met by having both front brakes on one hydraulic system, and both rear brakes on the other. This brake system configuration is highly preferred for rear wheel drive vehicles which typically have front suspensions with positive scrub radius. Positive scrub radius is produced by vehicle suspensions where packaging and strength requirements result in positive kingpin offset. To equip such vehicles with diagonal split brake systems (one front and the opposite rear brake on each of the two hydraulic systems) invites significant brake lead during stops with only one partial brake system functioning. To preclude this situation in the hands of the consumer, such vehicles are normally equipped with front-rear split braking systems. In addition, the front-rear split system requires only one proportioning valve, rather than two needed with diagonal split systems, and thus offers a slight cost advantage.

Given all the reasons above, the new harmonized brake standard should not preclude front-rear split braking systems. To avoid doing so it must contain a performance requirement for partial systems that is appropriate for such designs. The discussion below will demonstrate that the performance requirement proposed in FMVSS 135, a 155 m (509 foot) stopping distance from 100 km/h (62.1 mph) at a maximum pedal force of 500 N (112 pounds), clearly precludes existing front-rear split systems. To illustrate this point, consider the example RWD vehicle previously described in Appendix 3, Example Vehicles. Assuming the same 0.60 second brake system reaction time and equivalent multiplier in the stopping distance formula, the partial system requirement of FMVSS 135 would require an average deceleration of 0.27g (8.69 ft/s^2, 2.65 m/s^2). With a front-rear split brake system, the rears only portion of the test is equivalent to a rear brake fraction of 1.00 (or 100% rear brake balance). In the unladen vehicle condition, the rear axle limited deceleration can be calculated using equation 14 from Appendix 2, Derivation of Brake Balance Representations,

$$A = (ua)/[(a+b)(R_r)+(uh)] \tag{1}$$

or,

$$A = [(0.8)(42)]/[(105)(1.00)+(0.8)(21)] \tag{2}$$

$$A = 0.276 \text{ g} \tag{3}$$

For this particular vehicle configuration, the requirement of FMVSS 135 represents a minimum brake efficiency of 97.9%, assuming a tire-road peak traction coefficient of 0.80. This value is confirmed by the construction shown in figure 1. Given the variabilities discussed in Appendix 12, Variability, the preclusion of one wheel lock in the test procedure, etc., requiring nearly 98% efficiency is clearly not practicable. Therefore, front-rear splits are indeed precluded by this requirement.

For the laden vehicle condition, the rear axle limited deceleration is given by

$$A = [(0.8)(48)]/[(105)(1.0)+(0.8)(20)] \qquad (4)$$

$$A = 0.317 \text{ g} \qquad (5)$$

For the laden condition, the FMVSS 135 partial system requirement represents an 85.2% utilization requirement for a 0.80 tire road coefficient (see figure 2). The utilization requirement however, is not the difficulty with the laden vehicle. It is rather the reduced pedal force limit of 500 N (112 pounds) that creates problems for the laden vehicle. To illustrate the impact of the pedal force limit on brake system gain, focus on the laden vehicle achieving a deceleration of 0.27g (8.69 ft/s^2, 2.65 m/s^2) at 500 N (112 pounds) of pedal force.

The minimum brake force required to achieve a vehicle deceleration rate of 0.27g is given by

$$RBF(min) = AW \qquad (6)$$

where,

RBF = rear brake force in pounds

A = vehicle deceleration in g

W = vehicle weight in pounds

and

$$RBF = (0.27)(4200) = 1134 \text{ pounds} \qquad (7)$$

Rear brake torque required to produce this force is given by

$$RBT = (RBF)(RR) \tag{8}$$

where

RBT = rear brake torque, ft-lbs

RR = tire rolling radius, ft

or

$$RBT = (1134)(0.95) = 1077.3 \text{ ft-lbs} \tag{9}$$

The rear brake torque at any line pressure, P, larger than the proportioner knee, is given by

$$RBT = 2\{[(STR)(P_k-P_h)]+[(k)(STR)(P-P_k)]\} \tag{10}$$

where

STR = specific torque of a rear brake, ft-lbs/psi

k = proportioning valve slope

P = line pressure at the master cylinder, psi

P_k = proportioning valve knee, psi

P_h = rear brake holdoff pressure, psi

For the example RWD vehicle, we can substitute values to show that

$$1077.3 = 2\{[(0.60)(320-100)]+[(0.30)(0.60)(P-320)]\} \tag{11}$$

and solving for P yields,

$$P = 2579.2 \text{ psi} \tag{12}$$

For purposes of this discussion, we will treat the pedal force vs line pressure relationship as being predicted by

$$P = (P_f)(P_r)(BG) \tag{13}$$

where,

P_f = pedal force in pounds

P_r = pedal ratio

BG = booster gain

The term BG includes more complex factors than simply booster performance. It combines factors such as master cylinder diameter, booster diameter, etc, into a single term. Given this simple relationship, and the required line pressure value to comply with the proposed requirement of FMVSS 135, we can solve for the total booster gain required as

$$BG = P/[(P_f)(P_r)] \tag{14}$$

or,

$$BG = (2579.2)/[(112)(3.5)] = 6.58 \tag{15}$$

The value of pedal ratio of 3.5 is taken as typical for most power brake systems. Since this ratio is not changed throughout this analysis, the particular value selected is irrelevant, but was chosen to be representative.

We now have sufficient information to calculate the relationship between pedal force and vehicle deceleration that would be mandated for the full system by this partial system requirement of FMVSS 135. Given the parameters identified above, we can solve for the vehicle deceleration rate as a function of pedal force from the following relationship

$$A = TBF/W = TBT/[W(RR)] \qquad (16)$$

where,

TBF = total braking force, pounds

TBT = total brake torque, ft-lbs

and

$$TBT = 2\{[(STF)P]+[(STR)((P_k-P_h)+k(P-P_k))]\} \qquad (17)$$

where,

STF = specific torque of a front brake, ft-lb/psi

Equation (13) can be substituted into (17) to produce,

$$TBT = 2\{[(STF)(P_fP_r(BG))]+[(STR)((P_k-P_h)+(k(P_fP_r(BG))-P_k))]\} \qquad (18)$$

and (18) can be substituted into (16) to yield

$$A = 2\{[(STF)(P_fP_r(BG))]+[(STR)((P_k-P_h)+(k(P_fP_r(BG))-P_k))]\}/[W(RR)] \qquad (19)$$

Substituting appropriate values for our example RWD vehicle into (19) yields this relationship between pedal force and vehicle deceleration rate required by FMVSS 135:

$$A = 0.0113P_f + 0.0373 \qquad \text{for } P > P_k \qquad (20)$$

R.88 has a partial system requirement of achieving a stopping distance of 177 m (580.7 feet) from 100 km/h (62.1 mph) in both the laden and unladen conditions with a maximum pedal force limit of 500 N (112 pounds). Using the same 0.60 second reaction time, this translates into a required deceleration rate of 0.23g (7.41 ft/s^2, 2.25 m/s^2). Repeating a similar analysis for this requirement shows the required booster gain is 5.45, and the vehicle deceleration rate as a function of pedal force is given by

$$A = 0.0094P_f + 0.0373 \qquad \text{for } P > P_k \qquad (21)$$

FMVSS 105 requires a stopping distance of 456 feet (139 m) from 60 mph (96.5 km/h) in both the laden and unladen conditions with a maximum pedal force limit of 150 pounds (667 N). Repeating a similar analysis for this requirement shows that the minimum required booster gain is 5.12 and the full system vehicle deceleration rate as a function of pedal force is given by

$$A = 0.0088P_f + 0.0373 \qquad \text{for } P > P_k \qquad (22)$$

From this analysis of required booster gain it is obvious that both R.88 and FMVSS 135 represent increased stringency over FMVSS 105, with the proposed FMVSS 135 partial system requirement demanding a 28% increase in overall booster gain (from 5.12 to 6.58). This increase would require more than a minor adjustment to booster size or master cylinder diameter, both of which have significant impact on customer satisfaction regarding the "feel" of the brake system. Increased tooling costs, and packaging problems are anticipated. The calculated full system vehicle deceleration rate as a function of pedal force is shown for all three requirements in figure 3.

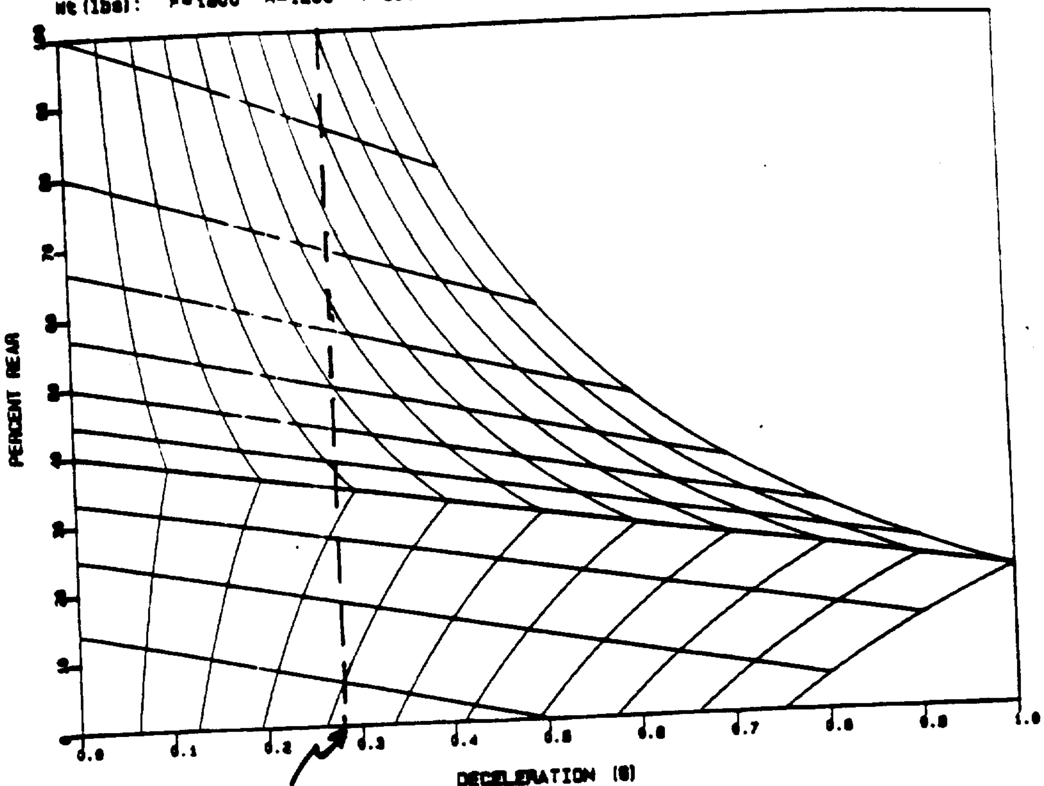
To illustrate a truly equivalent partial system requirement to FMVSS 105, we can calculate the deceleration rate of the example vehicle at a 112 pound pedal force from (10) and translate that into a 100 km/h stopping distance. Combining 112 pounds of pedal force and the FMVSS 105 minimum booster gain of 5.12 in equations 13, 10, 8, and 6 yields an FMVSS 105 equivalent deceleration of 0.22g (6.76 ft/s^2, 2.16 m/s^2), and this value translates into an equivalent stopping distance of 614 feet (187.2 m). This indicates that even the proposed requirement of R.88 represents an increase in stringency of 6% over this value, when both speed and pedal force limit differences are properly compensated.

GM test results suggest that the actual performance of rears only brake systems is strongly influenced by the degree to which the rear brakes have been burnished. This may be clearly seen by reviewing the GM test data in Appendix 8, GM Test Program. Table 9 of that Appendix gives the results of the RWD test vehicle with only the 36 stop burnish. The 1/2 system 1, GVWR stopping distance was 593 feet (180.8 m). Table 11 of that same Appendix gives results for the same car tested with an 86 stop burnish. In this case the stopping distance was 515 feet (157 m). The estimates calculated here are based on the assumption that both front and rear brakes are fully burnished.

In the interest of promoting harmonization, and to avoid the potential for precluding front-rear split brake systems, the agency should adopt the current requirement of R.88. Our test data indicate that this requirement is realistic and achievable, given sufficient burnish.

EXAMPLE RWD VEHICLE, UNLADEN

Wt (lbs): F=1800 R=1200 T=3000 CG (in)=21.0 WB (in)=105.0 RAD (ft)=0.950

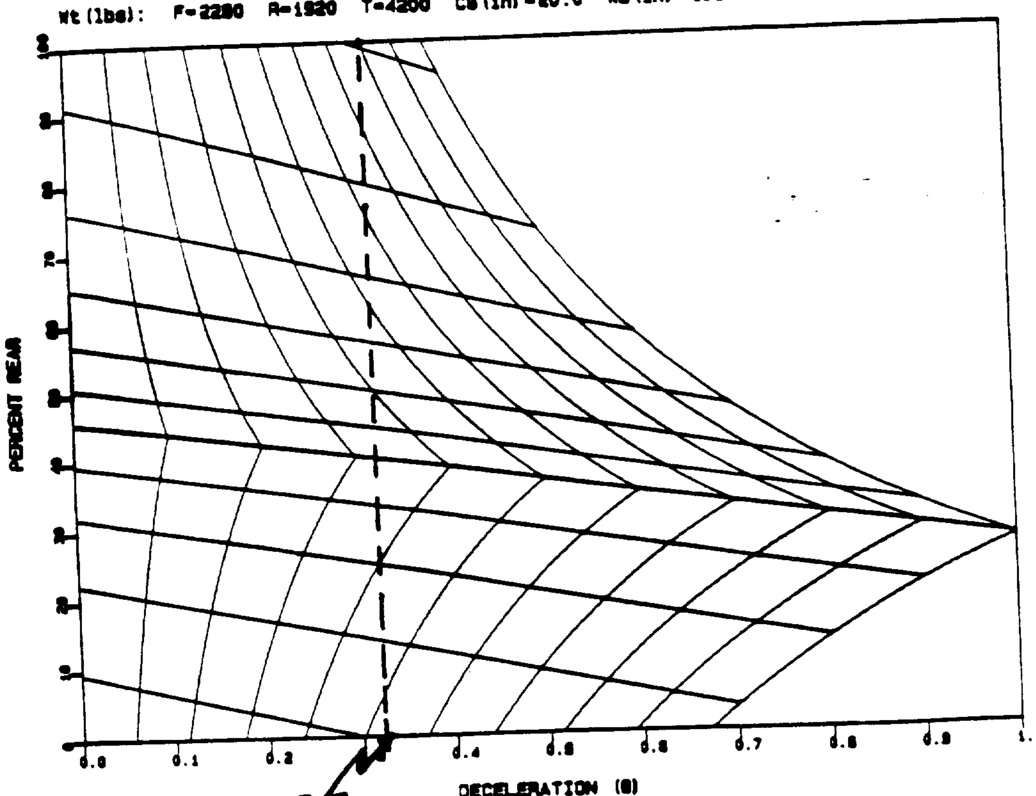


0.276g

Figure 1

EXAMPLE RWD VEHICLE, LADEN

Wt (lbs): F=2280 R=1920 T=4200 CG (in)=20.0 WB (in)=105.0 RAD (ft)=0.950



0.317g

Figure 2

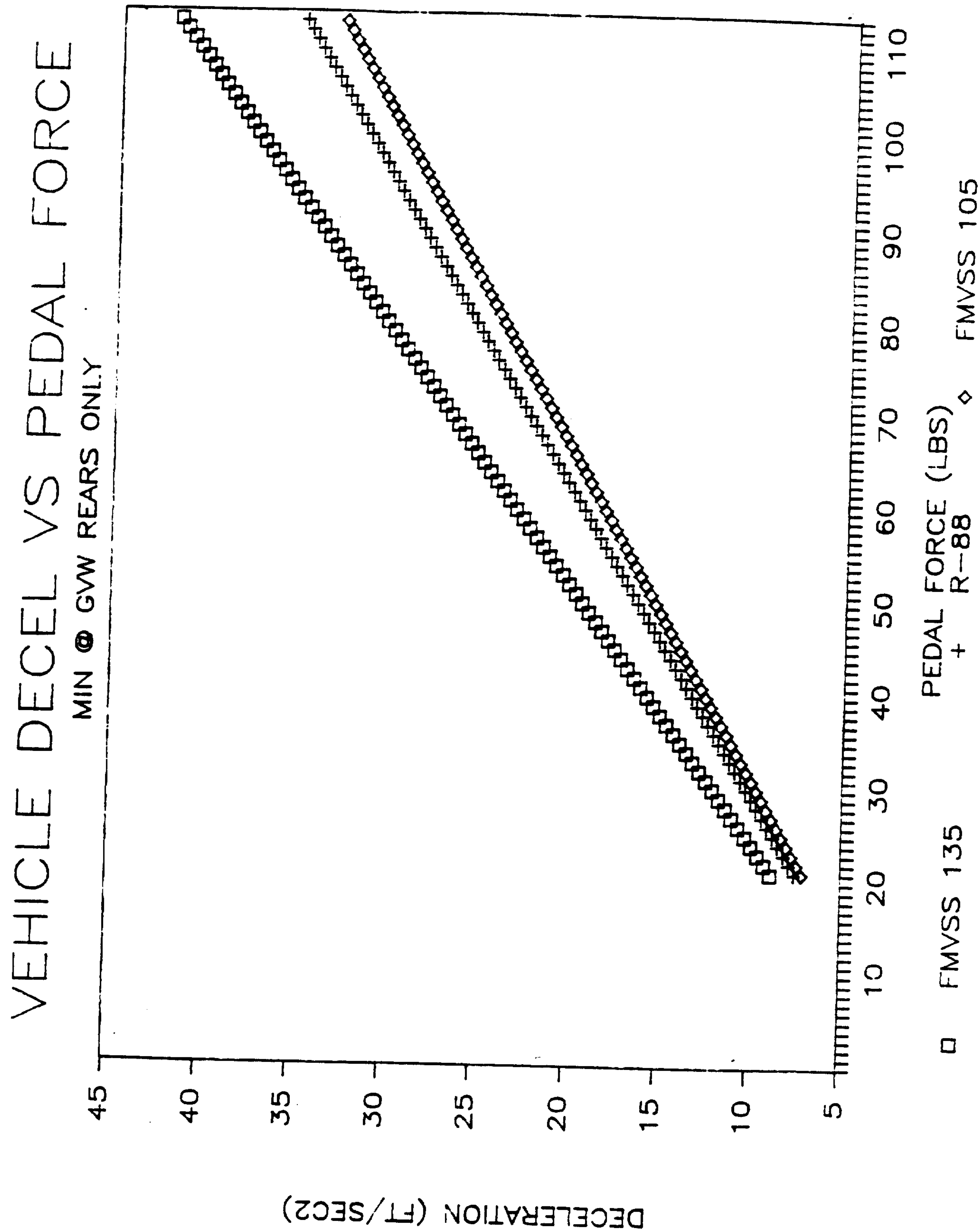

VEHICLE DECEL VS PEDAL FORCE
MIN @ GVW REARS ONLY
DECELERATION (FT/SEC2)
45
40
35
30
25
20
15
10
5
10
20
30
40
50
60
70
80
90
100
110
PEDAL FORCE (LBS)
□ FMVSS 135
+ R—88
◇ FMVSS 105

Figure 3

INOPERATIVE POWER ASSIST REQUIREMENT

OBJECTIVE

The purpose of this section is to review the inoperative brake power assist unit failure (system depleted) requirements, referred to hereafter as the "no power requirement", of the proposed FMVSS 135 in terms of both the pedal efforts and the stopping distances required, and to compare these to the requirements of FMVSS 105 and draft proposal R.88.

CONCLUSIONS

1. The no power test requirement of 155m (509 feet) proposed in FMVSS 135 is more restrictive than the equivalent requirements of FMVSS 105 and R.88.

2. Vehicles meeting the no power requirement of FMVSS 105 will require redesigning of one or more components in the brake system to meet the requirements of the proposed FMVSS 135.

3. The ECE draft R.88 no power stopping distance requirement of 177m (580.7 feet) is approximately 5% more stringent than the no power requirement of FMVSS 105.

RECOMMENDATION

Adopt a stopping distance of 177m (580.7 feet) for the no power requirement of FMVSS 135.

DISCUSSION

The proposed no power test in FMVSS 135 would require a vehicle to stop from 100 km/h (62.1 mph) in a distance of 155 m (509 feet) derived by using the mathematical relationship S = .05V + second reaction time, this translates into a minimum average vehicle deceleration of 0.27g (8.69 ft/sec^2). This is to be accomplished with a maximum pedal force of 500 N (112 pounds).

This proposed requirement may be compared to the similar requirement in FMVSS 105 which calls for a vehicle to stop from 60 mph in a distance of 456 feet or less with a maximum pedal effort of 150 lbs. Again assuming a brake system reaction time of 0.60 second, this distance translates into a minimum average deceleration of 0.28g (9.01 ft/sec^2). Thus, on a deceleration equivalence basis, the two standards are relatively comparable. However, much like the earlier comments regarding full service brake systems and other parts of the partial systems requirements, this is one performance requirement where pedal force is often the limiting factor. Therefore, the proposed standard must incorporate an increase in stopping distance to properly compensate for the 25% reduction in pedal force allowed.

General Motors offers the following analysis to show the effect of the change in the pedal force on no power stopping distance performance.

Consider the requirement of FMVSS 105 for no power tests. In order to achieve the required deceleration rate of 0.28g, our example FWD vehicle needs to develop a total brake force equal to

$$F = W\,g \tag{1}$$

$$= (4200)\,(0.28)$$

$$= 1176 \text{ pounds.}$$

If the tire rolling radius, RR, is taken to be 0.95 feet, then the total brake torque is given by,

$$T = F\ (RR) \qquad (2)$$

$$= (1176)\ (0.95)$$

$$= 1117 \text{ ft-lbs}$$

Given the other system parameters defined in Appendix 3, Example Vehicle, we can then solve for the minimum line pressure needed to produce this value of brake system torque (T) as,

$$T = 2P(ST_f) + 2\ (St_r)\ [(P_k - P_h) + k(P - P_k)] \qquad (3)$$

Where,

P = Line pressure
P_k = proportioning valve knee, psi
P_h = rear brake hold off pressure, psi
k = proportioning valve slope
ST_f = specific torque of front brake of example car, ft-lbs/psi
ST_r = specific torque of rear brake of example car, ft-lbs/psi

$$1117 = 2P\ (0.80) + 2\ (0.40)\ [\ (390-100) + (0.25)\ (P-390)]$$

which yields a minimum value of P = 535 psi.

Using the pedal ratio value of of 3.5:1 for the example car, and absent any power assist, the 150 pound pedal force limit of FMVSS 105 forces a maximum apply force to the master cylinder(F_{mc}) of,

$$F_{mc} = (3.5) \times 150$$

$= 525$ pounds.

Then, the maximum master cylinder area (A_{mc}) permitted is given by,

$$A_{mc} = F_{mc}/P \qquad (4)$$

$$= (525)/(535)$$

$$= 0.98 \text{ square inches}$$

Since this limit on master cylinder area is determined by the vehicle deceleration rate and the maximum pedal force limit allowed, we can then reestablish the maximum pedal force limit at 112 pounds, the FMVSS 135 limit, and calculate an equivalent vehicle deceleration. Given the identical brake system, at a 112 pound pedal force limit, the apply force to the master cylinder, absent any power assist, is given by,

$$F_{mc} = (3.5)\ 112$$

$$= 392 \text{ pounds.}$$

Given the master cylinder area fixed by the 105 requirements, the line pressure out of the master cylinder will be given by,

$$P = F_{mc}/A_{mc}$$

$$= (392)/(0.98)$$

$$= 400 \text{ psi}$$

The total brake system torque will be given by

$$T = 2\ (0.80)\ (400) + 2\ (0.40)\ [(390 - 100) + (0.25)\ (400 - 390)]$$

$$= 874 \text{ ft-lbs}$$

Then, the total brake force will be given by,

$$F = T\ /\ (RR)$$

$$= 874\ /\ (0.95)$$

$$= 920 \text{ pounds}$$

The vehicle deceleration rate will be given by,

$$g = F/W$$

$$= (920)\ /\ (4200)$$

$$= 0.22g$$

Assuming the same 0.60 second brake system reaction time, a 0.22g deceleration rate will produce a stopping distance of 614 feet from 100 km/h. Thus, by properly accounting for both the higher vehicle speed and lower pedal efforts required in the proposed FMVSS 135, we have shown that the no power test portion stopping distance should be 187 m (614 feet) rather than 155 m (509 feet).

General Motors notices that the draft R.88 stopping distance in the no power test is 177 m (580.7 feet), from 100 km/h with the vehicle in the laden condition. This represents approximately 5% increase in stringency over the performance requirement from that which we have just shown is equivalent to the FMVSS 105 requirement. To serve the cause of harmonization, General Motors recommends that the agency adopt the R.88 recommendation of 177 m(580.7 feet) for the no power test stopping distance.

To persist in the requirement for 155 m (509 feet) in this test portion would force manufacturers to adopt one or more of the following changes: increase pedal ratios, reduce master cylinder diameter, or increase foundation brake size. Increased pedal ratios are more difficult to package in smaller vehicles, and in many cases impossible to accommodate within the constraints of the steering wheel and instrument panel on the one hand, and the floorboard on the other. Reduced master cylinder diameters force longer master cylinders to be designed which are more difficult to package within the engine compartment. The other possible option would be to design low displacement brake systems. However in the past, such systems have been synonymous with high drag disc brake systems with attendant reductions in vehicle fuel economy. Increased foundation brake size would require redesigns of not only the foundation brakes but also tires and wheels which would add to the un-sprung weight of the vehicle and force considerable indirect expense in the form of tooling costs at both wheel and tire manufacturers as well as increased aerodynamic drag due to higher vehicle profiles.

In light of the fact that the agency has gone on record that no increase in stringency is intended over that of FMVSS 105, and to promote harmonization along with avoiding considerable unjustified expense to the manufacturer, the rational answer is to adopt an FMVSS 135 no power requirement the same as ECE draft R.88 This requirement of 177 m (580.7 feet) from 100 km/h (62.1 mph) represents an increase in stringency over FMVSS 105 of approximately 5%, however, in the interest of world wide harmonization of braking standards, General Motors can support such a requirement.

ENGINE FAILURE (SYSTEM CHARGED)

OBJECTIVE

The purpose of this Appendix is to review the engine failure (system charged) requirements of FMVSS 135 and compare them to those presently incorporated within ECE R13 and draft proposal R.88.

CONCLUSIONS

1. The partial system, engine off test in FMVSS 135 is more stringent than that incorporated in either R.88 or ECE R13.

2. The stopping distance requirement of 252.6 feet (77 m) from 100 km/h (62.1 mph) contained in the ECE draft R.88 proposal is essentially equivalent, after speed correction, to the ECE R13 requirement of 50 m (165 ft) from 80 km/h (48 mph).

RECOMMENDATION

1. If in the interest of harmonization, an engine off (system charged) requirement is deemed necessary, then the minimum performance level requirement for engine off should be established at 90% of the full system stopping distance modified as discussed in Appendix 17, Burnished Brake Performance.

DISCUSSION

The proposed FMVSS 135 has incorporated an engine off test requirement with brake power assist system fully charged similar in form to that presently contained in both ECE R13 and R.88. The 135 requirement sets a maximum stopping distance of 72 m (236 feet) from 100 km/h (62.1 mph). NHTSA stated in the Preamble discussion that their intent was to set this requirement at 90% of the full service brake performance requirement. However, the proposed full service brake system requirement in FMVSS 135 should be appropriately modified as discussed in Appendix 17, Burnished Brake Performance. Accordingly, the minimum performance level requirement for engine off should be established at 90% of the newly derived full system stopping distance.

The requirement in ECE R13 is a maximum stopping distance of 50 m (165 feet) from 80 km/h (48 mph). The requirement in draft proposal R.88 is a maximum stopping distance of 77 m(252.6 feet) from 100 km/h (62.1 mph).

A speed correction to the requirement of ECE R13 will produce a virtually identical requirement to that offered in R.88. Since energy which must be overcome during braking is proportional to the square of the speed, adjusting for the speed differences and not considering the reaction time correction, the equivalent stopping distance for ECE R13 at 100 km/h can be calculated as follows:

For ECE R13,

Stopping distance @ 100 km/h (62.1 mph) = $(62.1/50)^2$ x (stopping distance @ 50 mph)

Therefore, Stopping Distance @ 100 km/h = $(62.1/50)^2$ x 166

" " " = 256 feet

By this analysis, the 77 m (252.6 feet) presently proposed in R.88 represents a slight increase in performance requirement over the equivalent requirement in ECE R13. However, even the shorter proposed FMVSS 135 stopping distance of 72 m (236 feet) would require a further increase in performance of over 6% compared to R.88.

The agency's proposed requirement for this particular test is rather surprising considering the fact that FMVSS 105 has no similar test requirement. Under the auspices of harmonization, and absent any demonstrated safety need for such a requirement, it would have been expected that the adoption of the European test requirement would have been proposed; not a 6% increase in stringency beyond but decreased the European standards. While the adoption of any such requirement constitutes an increased performance requirement over FMVSS 105, in the interest of harmonization, GM would support the addition of the engine off requirement provided an appropriate level of stopping distance based on R13 is established.

FAILED ANTI-LOCK REQUIREMENTS

OBJECTIVE

The purpose of this Appendix is to review and compare the failed anti-lock requirements of the proposed FMVSS 135 to the requirements of FMVSS 105, and draft proposal R.88.

CONCLUSIONS

1. The failed anti-lock system requirements of the proposed FMVSS 135 are more stringent than those of FMVSS 105, and R.88.

2. The failed anti-lock requirements of the proposed FMVSS 135 are design restrictive and will inhibit the introduction of this technology into new products.

RECOMMENDATIONS

1. The agency should treat failed anti-lock systems as a partial system failure and set the stopping distance accordingly.

2. In the interest of harmonization, the agency should adopt the failed anti-lock requirements of R.88, and permit a stopping distance of 177 meters (580.7 feet) from 100 km/h (62.1 mph) with the vehicle in the laden condition.

DISCUSSION

The proposed failed anti-lock requirements of FMVSS 135 would permit a maximum vehicle stopping distance of 80 m (263 ft.) from 100 km/h (62.1 mph), both laden and unladen. Although FMVSS 135 discusses "structural or functional" failures, there is no specific definition of "failure", a term which will require subsequent clarification. This requirement establishes a minimum average equivalent vehicle deceleration of 0.55g (17.71 ft/s^2, 5.39 m/^{2}) after correcting for a 0.6 second reaction time, as compared to the full system performance requirement of a minimum average equivalent vehicle deceleration of 0.70g (22.54 ft/s^2, 6.86 m/s^2).

The proposed failed anti-lock requirements of FMVSS 135 are obviously more stringent than those in either FMVSS 105 or R.88. The failed anti-lock requirements of FMVSS 105 and draft proposal R.88 both treat this test as a partial system failure and permit distances commensurate with this performance level. In the case of FMVSS 105, a laden vehicle stopping distance of 456 feet (140 m) from 60 mph (96.5 km/h) is permitted with a maximum pedal effort of 150 pounds (667 N), and in R.88 a laden vehicle stopping distance of 177 meters (580.7 feet) from 100 km/h (62.1 mph) is specified with a maximum pedal effort of 500 N (112 pounds). As was shown in Appendix 20, Inoperative Power Assist Requirements, the FMVSS 105 requirement is equivalent to a laden vehicle stopping distance of 187.2 m (614 feet) at the speed and pedal force limits of R.88. Thus, the current requirements of R.88 already include an increase in performance over that necessary to meet FMVSS 105 failed anti-lock performance limits. However, in the interest of harmonization, GM recommends the agency adopt the stopping distance of R.88, even though this would require some models to be redesigned.

Future anti-lock systems will likely contain electrical and hydraulic power sources integrated with the basic vehicle braking system. The hydraulic power source may be electrically driven and controls may be integrated within the same electronics as the anti-lock system. Thus, an anti-lock electrical malfunction could affect the primary service brake systems. Therefore, such systems would be properly considered to be of the same partial system performance class as simple power assist or partial system failures. Thus the stopping distance for failed anti-lock would have to be treated as it currently is in FMVSS 105 and is proposed in R.88 in order to avoid impeding the introduction of these new systems.

FAILED VARIABLE PROPORTIONING SYSTEMS

OBJECTIVE

The purpose of this Appendix is to compare the requirements for failed variable proportioning valves in the proposed FMVSS 135 to those in FMVSS 105, draft proposal R.88, and ECE R13.

CONCLUSIONS

1. The proposed failed variable proportioning valve requirements of FMVSS 135 are more stringent than those of FMVSS 105, draft proposal R.88, or ECE R13.

2. The failed variable proportioning valve requirements of proposed FMVSS 135 will discourage introduction of this technology in future vehicle programs.

RECOMMENDATION

The agency should adopt the failed variable proportioning valve requirements of R.88, i.e., a laden vehicle stopping distance of 177 m (580.7 feet) from 100 km/h (62.1 mph).

DISCUSSION

The failed variable proportioning valve requirements of proposed FMVSS 135 permit a maximum stopping distance from 100 km/h (62.1 mph) of 80 m (263 feet) in both the laden and unladen conditions. This requirement is a marked increase in stringency from FMVSS 105 which permits a stopping distance of 456 feet (140 m) for the laden vehicle from 60 mph (96.5 km/h). This FMVSS 105 requirement is equivalent to a stopping distance of 187.2 m (614 feet) under the test conditions of FMVSS 135.

GM recommendations for other partial systems requirements of FMVSS 135 (no power, partial systems, and failed anti-lock) all call for the adoption of the R.88 requirement, in spite of the fact that R.88 represents an increase in stringency over FMVSS 105. A similar recommendation is made for the case of the failed height/load sensing proportioner valve. The adoption of the current requirement in FMVSS 135 for failed height/load sensing proportioners would represent a significant departure from R.88, the draft proposed international braking standard developed after more than four years of effort on the part of the international brake community.

Promulgation of such a dramatically different requirement is unwarranted because it is not based on accident data or analysis suggesting a safety need, nor would it result in upgrading vehicle braking systems. Retaining an 80 m (263 ft) stopping distance requirement for failed variable proportioners would simply result in manufacturers omitting such devices from future products.

The only use of variable proportioners is to adjust the balance (specifically the rear brake output) so that balance can be closer to ideal in both the laden and unladen conditions. It does so by restricting hydraulic pressure to the rear brakes when the vehicle is unladen, and removing the restriction when the vehicle is laden and more rear brake power can be applied to the road without lockup.

Under the conditions of the proposed FMVSS 135, a vehicle would have to meet a stopping distance only 15 m (49 feet) longer than the cold effectiveness full system test with the valve in the wrong position for the loading condition. In other words, the vehicle would have to be tested lightly loaded with the full pressure to the rear brakes. This would result in a rear skid limited stopping distance significantly longer than the full system stopping distance. Similarly, when tested at GVWR the valve would be failed into the lightly loaded position. The vehicle would have to meet the specified distance with the rear brakes receiving the restricted pressure, and would not have sufficient rear brake output. The only way a manufacturer could assure that the vehicle would meet these failed valve requirements would be to balance the base brake system to meet these extremes. This would greatly diminish the value of the relatively expensive height/load sensing proportioners and discourage their use.

To unduly penalize vehicles equipped with such devices seems contrary to the interests of the motoring public. Since such devices are only now being introduced to the vehicle population in limited applications, keeping the proposed FMVSS 135 requirement will only discourage their development for future vehicle programs.

GM recommends adopting the requirements of R.88 which would promote harmonization, even though it is at the expense of an increase in stringency over FMVSS 105.

PARKING BRAKE REQUIREMENTS

OBJECTIVE

The purpose of this section is to review the test conditions and performance requirements for the static and dynamic parking brake systems of FMVSS 135 and to compare them to those contained in the regulations FMVSS 105, ECE R13 and ECE Draft R.88.

CONCLUSIONS

1. The expression of a dynamic parking brake requirement in terms of stopping distance is more stringent than the specification of a mandatory deceleration rate that must be achieved during the stop such as specified by both R13 and R.88.

2. Based on the comparison of the static grade holding requirements on a 20% slope contained in FMVSS 105 and FMVSS 135, the lower application forces of FMVSS 135 requires higher parking brake system gains than FMVSS 105. This represents an increase in stringency over the current standard.

RECOMMENDATIONS

1. Adopt the R.88 or ECE R13 method of regulating dynamic parking brake performance; a deceleration that must be achieved rather than a stopping distance.

2. Adopt 400 N (90 lbs) hand apply force limit as specified in the Draft R.88 procedure.

3. Given that the number of brake burnish stops will be increased, the parking brake test should be placed ahead of the fade heating schedule in the proposed FMVSS 135 test sequence.

DISCUSSION

The parking brake requirements called for in FMVSS 135 differ significantly from those in either FMVSS 105 or the draft harmonized proposal R.88.

Apply Force

The allowable pedal force limit for foot operated systems in static hill holding is reduced in the proposed FMVSS 135 from the FMVSS 105 limit of 556 N (125 lbs) to 500 N (112 lbs) while the test grade has been reduced from 30% to 20%. These changes bring the requirements of FMVSS 135 into concurrence with the requirements of draft proposal R.88. However, FMVSS 135 reduces the allowable apply force limit for hand operated parking brake systems from 400 N (90 lbs) specified in the FMVSS 105 and in draft proposal R.88 to 320 N (72 lbs). This reduction in the apply force has the effect of requiring an increase in brake system gain as explained later in this appendix. While the agency cited some human factors data to support the change to 500 N (112 lbs) for foot apply, the notice failed to offer any similar data that demonstrates a need for a lower hand apply force.

Dynamic Test

Likewise, FMVSS 135 would add a dynamic parking brake requirement based on 2 m/s^2 (6.56 ft/s^2) deceleration rate similar to that cited in the draft proposal R.88, except for the one significant change. FMVSS 135 would specify a stopping distance of 73 m (238 feet) while R.88 does not specify a stopping distance requirement. Instead, R.88 would require that a "mean fully developed" deceleration rate of 2 m/s^2 (6.56 ft/s^2) be achieved during the stop without requiring deceleration over the entire stop to average this value. This necessitates some higher deceleration to make up for system reaction time as would be required by the stopping distance limit in FMVSS 135. The system reaction time used by NHTSA in translating deceleration to stopping distance appears to have been the same 0.36 second used for deriving the full system effectiveness requirements as discussed in Appendix 9, Brake System Reaction Time. Appendix 9 demonstrates that 0.36 second is inappropriate for hydraulic apply systems. It is clearly erroneous for mechanical parking brake apply systems that react more slowly than hydraulic systems.

The FMVSS 135 would require an attempt for a best stop at maximum deceleration without exceeding the pedal force limit or locking wheels. This test difficulty has been experienced during NHTSA evaluation of the proposed standard as cited on page V-47 of the regulatory Evaluation which states that "an attempt was made to achieve maximum deceleration without exceeding the allowable control force or locking the wheels. This was found difficult to do because it was hard for the test driver to predict where wheel lockup would occur." This test difficulty supports a test requirement of achieving a specified deceleration as R13 and R.88 call for, rather than a stopping distance where the driver is more likely to run into modulation problems and encounter wheel lock.

The requirement of a 6.56 ft/sec^2 (2 m/s^2) deceleration over the entire stop represents a need to slow the vehicle with the rear brakes operating at 89% of the limit of adhesion without wheel lock up (on a 0.80 tire-road coefficient) for our example vehicle in the unladen condition. (See Appendix 17, Burnished Brake

Performance) This is a more stringent requirement than that of either R.88 or ECE R13.

Static Grade Holding

The analysis in Attachment A is offered to compare the static 20% grade holding requirements proposed in the FMVSS 135 with the requirement of FMVSS where the 20% grade provision is used for validating the parking brake systems on vehicles equipped with the automatic transmissions.

That analysis indicates that the static hill holding requirements of FMVSS 135 require parking brake system gains higher than that required under the provision (20% grade) of the FMVSS 105 standard indicating that the FMVSS 135 proposal is an increase in stringency. Further, the reduction in the hand apply force represents a deviation from draft R.88 procedure and thereby diminishes the chance of FMVSS 135 being adopted as a harmonized standard.

Park Brake Test Placement

With the relatively short burnish schedules proposed in FMVSS 135 and the placement of the parking brake test after the fade test, the performance of the laden vehicle in the dynamic parking brake test is very dependent upon the particular choice of fade schedule option selected in the FMVSS 135 test. For the vehicles tested by GM to the proposed 80 snub fade procedure (alternative 1), the dynamic parking brake requirement was met, but the same vehicles tested with the 15 snub fade procedure (alternative 2), both failed the dynamic parking brake requirement. This suggests the final requirements for dynamic parking brakes cannot be formulated until the fade heating cycle is established.

If the burnish procedure is changed to incorporate 200 stop as cited in GM comments contained in the Appendix 10, then the parking brake test can be moved ahead of the fade and recovery tests and the dependency upon the fade schedule would be eliminated.

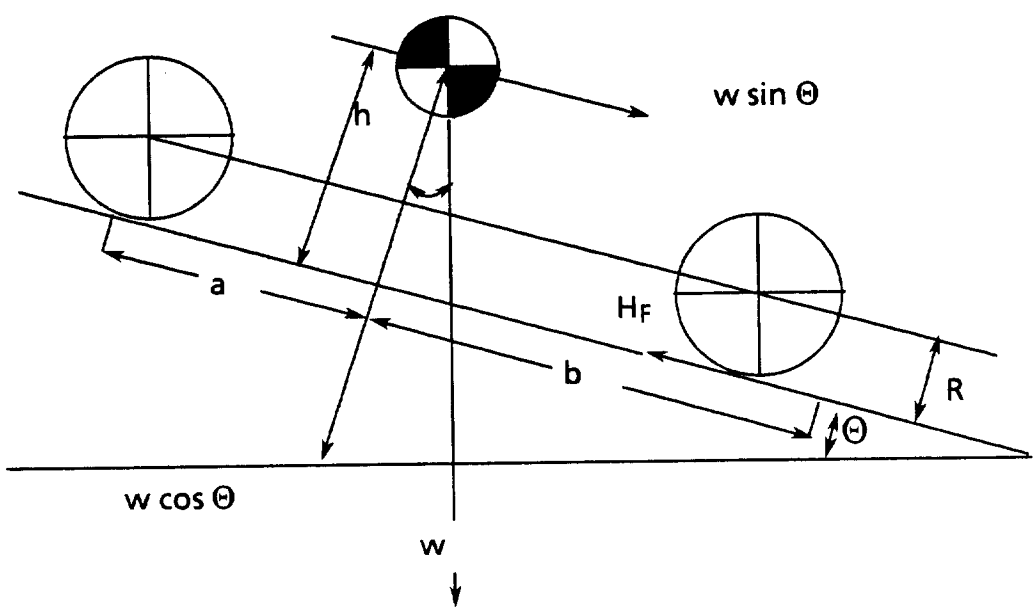
ATTACHMENT A

ASSESSMENT OF STATIC GRADE HOLDING REQUIREMENTS IN FMVSS 105 AND 135 (PROPOSED)

FMVSS 135 calls for the parking brake system to hold on a 20% grade with a pedal force limit of 112.4# for a foot operated pedal, and 71.9# for a hand operated system.

FMVSS 105 allows the parking brake system to be tested on a 20% grade with a maximum pedal effort of 125# on a foot operated pedal, and 90# limit on a hand operated system, [if a parking pawl that meets a barrier impact test at GVW is used to hold on the otherwise required 30% grade.]

The question to address is, are these two 20% grade requirements of equal stringency? To answer this question, let's begin with the following vehicle diagram.



The force seeking to move the vehicle down the hill is given by

$$F = W\sin\Theta$$

@ 20% grade

$$\Theta = \text{Arctan}\ (0.20)$$

$= 11.3°$

on a 20% grade

$F = W\sin(11.3°)$
$= 0.196W$

Given the above, we have to account for the reduction in allowable pedal force as follows:

The horizontal force generated at the road surface is given by, in general

$H_F = 2\eta P_F$
where η = system gain
and P_F = foot operated pedal force

<u>For FMVSS 135,</u>

A foot operated system must have,

$$0.196W = 2\eta_F' (112.4)$$

$$\eta_F' = \frac{0.196W}{2(112.4)}$$
$$= 0.872(10)\text{-}3W$$

A hand operated system must have,

$$0.196W = 2\eta_H' (71.9)$$

or

$$\eta_H' = \frac{0.196W}{2(71.9)}$$
$$= 1.363(10)^{-3}\ W$$

<u>For FMVSS 105,</u>

A foot operated system must have,

$$0.196W = 2\eta_F'' (125)$$

$$\eta_F'' = \frac{0.196W}{250}$$

$$= 7.84(10)^{-4}W$$

and, a hand operated system must have,

$$0.196W = 2\eta_F''(90)$$

$$\eta_F'' = \frac{0.196W}{180}$$

$$\eta_F'' = 1.089(10)^{-3}W$$

In summary,

STANDARD	SYSTEM GAIN	
	FOOT OPERATED	HAND OPERATED
FMVSS 105 (20% grade)	$0.784(10)^{-3}W$	$1.089(10)^{-3}W$
FMVSS 135 (20% grade)	$0.872(10)^{-3}W$	$1.363(10)^{-3}W$

FADE HEATING CYCLES

OBJECT

This Appendix reviews the fade heating cycles of FMVSS 105, draft proposal R.88, and both proposed alternatives of FMVSS 135 for their relative influence on brake system behavior and their appropriatenessin assessing brake system performance in the hands of the customer.

CONCLUSIONS

1. Through the first seven stops, the fade heating cycles of all the schedules are roughly equivalent in terms of brake temperatures and changes induced in brake system output.

2. The maximum brake output changes in all fade heating cycles studied for this response occur relatively early in the test. For the vehicles studied by GM, this normally occurs at or about the seventh stop in the short fade heating sequences. For the long 80 snub proposed alternative 1 of FMVSS 135, the maximum change in front brake output occurs at about the 20th snub, and subsequent test snubs are redundant.

3. Comparison of fade heating cycles on the basis of peak temperature is both inaccurate and irrelevant. A time at temperature, or an equivalent energy per unit distance or time basis provides a more effective assessment of stringency.

4. Friction materials demonstrate smaller changes in output during a fade heating cycle if they have been previously exposed to similar service. This observation is based not only on the comparison of FMVSS 105 first and second fade performance, but also the relative behavior of friction

materials studied after extended usage in the hands of customers.

5. Semi-metallic friction materials respond to fade heat cycles differently than do asbestos reinforced friction materials.

6. Based on an energy per mile or an energy per minute basis, the fade heat cycles of FMVSS 105, FMVSS 135 alternatives 1 and 2, and R.88 all exceed the requirements needed to simulate the demands on the vehicle brake system made by the customer in a Pikes Peak descent at GVW. The closest approximation to this severe customer situation is the R.88 fade heating cycle.

RECOMMENDATIONS

1) The fade heating cycle of R.88 should be adopted in FMVSS 135, unless significant additional test data which support other options become available. An alternative proposal would be to extend the interval in proposed alternative 2 of FMVSS 135 to produce inputs to the brake system which are equivalent to R.88.

2) The performance during the fade testing sequence (fade heat cycle, hot stop, and recovery) should be based on baseline snubs run immediately prior to fade heat cycles, as is presently prescribed in FMVSS 105.

DISCUSSION

The two proposed alternative fade heating cycle of FMVSS 135 differs from the protocol specified in FMVSS 105, R.88, and ECE R13 is several key areas. Both proposed fade heating cycles of FMVSS 135 were intended to meet the agency's concern that a certification test fade heating cycle "insure adequate braking capability during and after exposure to the high brake temperatures caused by prolonged or severe use". The first, proposed alternative 1, calls for a laden vehicle to make 80 snubs from 55 km/h to 25 km/h (34.2 to 15.6 mph) at a deceleration rate of 2.4 m/sec^2 (7.9 ft/sec^2) with 15 second intervals between brake applications. This option is based on SAE recommended practice J1247, a flat track simulated mountain descent, with which GM has had considerable experience.

Alternative 2 fade heating cycle proposed in FMVSS 135 calls for a laden vehicle to make 15 snubs at a deceleration rate of 3.0 m/sec^2 (9.8 ft/sec^2) from a speed of 120 km/h (74.6 mph) or 80% of V_{max}, whichever is slower, to one half the initial speed with 30 second intervals between brake applications.

The fade heating cycles in FMVSS 105 are substantially different from any of the cycles currently under consideration in that the vehicle brakes are exposed to high temperatures on two separate occasions. Following three laden baseline stops from 30 mph (48.3 km/h) at a deceleration rate of 10 ft/sec^2 (3.05m/sec^2), the first fade heating cycle consists of the laden vehicle making five stops from 60 mph (96.5 km/h) at a deceleration rate of 15 ft/sec^2 (4.57 m/sec^2) and then five stops from 60 mph (96.5 km/h) at the maximum deceleration rate between 5 and 15 ft/sec^2 (1.52 and 4.57 m/sec^2). These ten stops are made at 0.40 mile (0.64 km) intervals, and together constitute the first fade heating cycle of FMVSS 105. Following five recovery and 35 reburnish stops, the laden vehicle must make ten stops from 60 mph (96.5 km/h) at a deceleration rate of 15 ft/sec^2 (4.57 m/sec^2) and an additional five stops from 60 mph (96.5 km/h) at the maximum deceleration rate between 5 and 15 ft/sec^2 (1.52 and 4.57 m/sec^2). These fifteen stops comprise the second fade heating cycle in FMVSS 105. For purposes of this response, GM has focused its testing and analysis on the first fade heating cycle in FMVSS 105 as being similar to the heating cycles in R.88 and FMVSS 135 because the friction materials have not been exposed to prior heating. As we will show later, the behavior of friction materials is different in the second fade heating cycle of FMVSS 105. System performance is improved by the prior exposure to the first fade, cooling, and reburnish stops.

The fade heating cycle of R.88 follows two baseline snubs in the laden condition from 80% of V_{max} ((limited to 120 km/h (74.6 mph)) at a deceleration rate of 3 m/sec^2 (9.8 ft/sec^2). During the R.88 fade heating cycle, the laden vehicle must make 15 snubs from 80% V_{max} (limited to 120 km/h (74.6 mph)) to 40% of V_{max} at a pedal force equal to that used in the baseline snubs, with an interval of 45 seconds between brake applications. Proposed alternative 2 is different from the R.88 heating cycle in at least two important ways: 1) proposed alternative 2 specifies a deceleration rate rather than a pedal force from baseline snubs; and 2) the interval between brake applications is 30 seconds in proposed alternative 2 rather than the 45 second interval of R.88.

The shorter 30 second interval in the FMVSS 135 proposed alternative 2 fade heating cycle is based on agency tests of brake temperatures in several vehicles. The agency Regulatory Evaluation and the Preamble of the Notice both address this issue, and the concern on the part of the agency seems to be that the R.88 heating cycle produces lower temperatures than does FMVSS 105. As we will show later, the agency is unnecessarily concerned with three aspects of fade testing.

First, the agency expresses concern that the brake temperatures during the R.88 fade heat cycle do not compare to the second fade and recovery temperatures of FMVSS 105. This concern is unnecessary because the second fade of FMVSS 105 is not comparable to any initial fade cycle. In the second fade and recovery portion of FMVSS 105, the brake materials have experienced a prior exposure to high temperature, and the brake output is more consistent as a result of this exposure.

Second, the agency fears that lower brake temperatures may fail to predict the fade behavior of systems that might have a higher thermal threshold than the R.88 schedule would evaluate, yet experience large output changes upon reaching this threshold. This fear must be based on the assumption that it is necessary to reach the temperatures that the FMVSS 105 fade heating cycle generates in order to experience fade in new brakes, an assumption we will later show to be false. Another assumption necessary to validate the agency's temperature concern is that real customers are likely to experience the brake temperatures produced by the fade heating cycle of FMVSS 105. A later portion of this response section will address this issue.

The third important misunderstanding is the assumption that the fade behavior of new friction materials is directly analogous to the fade response of used friction materials in the hands of the consumer. Differences between the responses of new and used brake friction materials to fade test will be discussed below, based on both GM and NHTSA test data.

As noted above, the comparison of fade heat cycles on the basis of peak temperatures is not necessarily valid. The peak temperatures measured in a brake system are not only a function of where they are measured, the vehicle loading condition, the configuration of air dams if present, the size, construction, and material used for wheels, but also the foundation brake size and the distribution of braking forces between the front and rear axles. These variables may all be carefully controlled, and yet the same identical vehicle tested to two disparate procedures may produce identical temperature results. Likewise, the same identical vehicle may produce different temperatures on approximately equivalent procedures if the cooling intervals or test speeds are different, or the rate of energy input is different in the two procedures. In terms of equitable comparisons of various fade heat cycles, and their effect on brake system performance, GM's extensive experience in brake temperature analysis strongly supports a comparison on the basis of total brake energy input and even more importantly brake power, or the rate of energy input. The issue should not be brake system response, i.e. peak temperature, but rather energy or power inputs representative of customer needs.

Comparing two fade heat cycles on total energy input gives an equitable measure of the total amount of work the vehicle's brake system has to accomplish without experiencing changes in performance beyond certain reasonable limits. For brake friction materials, the rate at which energy (power) is delivered to the brakes is likewise an important basis for comparison. This basis (i.e. time at temperature) yields a measure of the rate at which vehicle brake systems must deal with energy, either by storage or by dissipation. New, relatively unused brake friction materials change in output rather quickly in response to power, and more gradually to energy differences in test schedules. For purposes of certification testing, the most important parameter to consider in a fade heating cycle is the power, or rate of energy input, the vehicle's braking system must accommodate in the schedule.

The first fade heating cycle of FMVSS 105 can be compared to both fade heating cycles of FMVSS 135 on the basis of both energy and power. For the first fade heating cycle of FMVSS 105, these calculations were made assuming all ten stops were run at both 5 and 15 ft/sec^2 (4.57 m/sec^2) deceleration rates. For the fade heating cycles of FMVSS 135, proposed alternative 2 was analyzed assuming the limit on vehicle speed (V max) was 120 km/h (74.6 mph). For the comparison based on power, the time basis was the time the vehicle was actually undergoing braking and not the total time to run the heat cycle test. The results of this analysis are shown in Table 1 where it can be seen that either proposed alternative 1 or 2 of FMVSS 135 is more demanding than FMVSS 105, on either an energy or a power basis. On the basis of energy, proposed alternative 1 of FMVSS 135 produces more than twice the braking energy of the first fade heat cycle in 105, and proposed alternative 2 produces energy 1.7 times that of FMVSS 105, where the energies are normalized to vehicle mass. On the basis of power, proposed alternative 1 is more than three times more intense than FMVSS 105, and realistically should be discarded as a viable alternative to FMVSS 105 or R.88 on that basis alone. Proposed alternative 2 of FMVSS 135 is more than twice as stringent as 105's worst case first fade heating cycle, and likewise should be discarded as a realistic replacement. Power values are normalized to vehicle mass to permit comparisons for various vehicles.

Since the energy and power produced by the fade heating cycle of R.88 is dependent upon a constant pedal force rather than a constant vehicle deceleration, theoretical calculations of either could not be made in the absence of pedal force gain estimates. Due to the magnitude of the testing required to obtain reliable estimates for many different vehicles, GM has not gathered or estimated these values. A proper approach would be to determine the maximum and minimum vehicle pedal force gain relationships permitted by the other test requirements, i.e., partial systems, etc., and calculate the resulting range of energy and power that would result.

GM vehicle tests of brake system response to fade heat cycle exposure have provided a quantitative basis for review. In these tests of vehicles equipped with full instrumentation including torque wheels, front and rear brake gain throughout both FMVSS 105 fade heat cycles and through both proposed alternative 1 and 2 fade heat cycles of FMVSS 135 have been measured. In the analysis of these data, the brake outputs have not been corrected for holdoff pressures since only relative comparisons are necessary.

In Figures 1 and 2, the behavior of the RWD test vehicle equipped with semi-metallic front disc brake friction materials is shown. The front brake output during the first fade heat cycle of FMVSS 105 initially increases through the first three stops, and then decreases over the next four stops, and subsequently remains essentially stable over the last three stops. At the end of the first fade heating cycle, the front brake output has dropped from 1.75 ft-lb/psi (.34 Nm/kPa) during the baseline snubs to about 1.25 ft-lb/psi (.25 Nm/kPa), or a decrease of about 29%. During the second fade heat cycle of FMVSS 105, the front brake gain has dropped, after 15 snubs, to about 1.60 ft-lb/psi (.31 Nm/kPa)from a baseline value of 1.90 ft-lb/psi (.37 Nm/kPa), or a decrease of about 16%.

This comparison shows the semi-metallic friction material used in the front disc brake of this particular test vehicle undergoes a smaller change in output during the second fade heat cycle of FMVSS 105 than it did during the first heat cycle, in spite of the fact that the second heat cycle has 50% more stops. This observation is evident for the other GM test data, and suggests that friction materials become more resistant to high power inputs if they have experienced a similar exposure previously. This observation, supported by subsequent GM test data, suggests that the first exposure of brake friction material to a fade heating cycle may not effectively represent the behavior of that same material after a customer has driven a vehicle for several hundred miles. Additional data are needed to make that determination, which is directly relevant to the agency's concern regarding the behavior of vehicle braking systems after severe or prolonged use. This observation points to a need for additional test data to determine the relevancy of first exposure response in emulating the behavior of brake systems in the hands of the customer.

During extensive used vehicle testing conducted by both the agency and GM, using the agency's own VRTC test procedure, brake systems equipped with semi-metallic friction materials on the front disc brakes showed no similar tendency to fade following several thousand miles of customer usage. This data is available to the agency from its own files and therefore is not included in this response.

The same RWD vehicle when equipped with asbestos friction materials on the front disc brakes demonstrates a different brake system response to the fade heating cycles of FMVSS 105. The results of GM's test of this particular configuration are shown in figures 3 and 4. During the first fade heating cycle, figure 3, the front brake output decreases by about 50% within the first 5 stops, and then recovers during the second 5 stops. Again, following first recovery and 35 reburnish stops, the front brake response during the second fade heating cycle shows a similar trend, but to a smaller degree (Figure 4). Just as before, it appears that the prior exposure to fade heating cycle temperatures improves the consistency of the front (and rear) brake output during fade heating cycle exposure.

When the asbestos front disc brake friction materials are exposed to the proposed alternative 2 fade heating cycle of FMVSS 135 in the RWD vehicle (figure 5), the front brake output behavior resembles that seen in the first fade of FMVSS 105, but the higher power level exposure of alternative 2 coupled with the absence of prior fade heat cycle exposure combine to produce an over recovery condition. The front brake gain is higher at the end of the fade heating cycle than it is in either FMVSS 105 baseline on the same system.

The FWD vehicle with semi-metallic friction materials on the front disc brakes demonstrates response similar to the RWD vehicle equipped with the same type front brake friction materials in FMVSS 105 fade heating cycle exposure. The front and rear brake output during FMVSS 105 heat cycle exposure is shown in Figures 6 and 7. During the first fade heating cycle of FMVSS 105, (Figure 6) the front brake output decreases from about 1.25 ft-lb/psi (.25 Nm/kPa) in the baseline to approximately 0.85 ft-lb/psi (.17 Nm/kPa) by the seventh stop, or a loss in output of 32%. The baseline for the second fade heating cycle was unfortunately lost due to a computer malfunction, but can be reasonably assumed equal to the first (Figure 7). With this assumption, the front brake output during the second fade heating cycle of FMVSS 105 drops to 1.15 ft-lb/psi (.23 Nm/kPa) by the seventh stop, and ultimately drops to slightly less than 0.90 ft-lb/psi (.18Nm/kPa) near the end of the cycle. After an equivalent exposure of seven stops, the front brake output during the second fade heating cycle is only reduced 8% from baseline as compared to the 32% drop in the first cycle. This observation clearly supports the hypothesis that prior exposure to fade heating cycles improves front (and rear) brake output stability.

The same vehicle configuration, when exposed to the proposed alternative 2 fade heating cycle of FMVSS 135 shows a drop in front brake output similar in magnitude to that observed in the first fade heating cycle of FMVSS 105. After the thirteenth stop, the front brake output has dropped to approximately 0.90 ft-lb/psi (.18 Nm/kPa), just as in the 105 fade heating cycles. This finding is based on the results shown in Figure 8 for this particular vehicle configuration. Repeat tests to the FMVSS 105 fade and recovery procedures yield similar results, as shown in Figures 9 and 10.

The proposed alternative 1 fade heating cycle of FMVSS 135 produces similar changes in brake outputs of the FWD vehicle equipped with semi-metallic front disc brake friction materials. The results of GM's test of this fade heating cycle are shown in Figure 11. In this test, every fifth stop was recorded due to a limit of on-board computer memory. These test results are quite interesting as they show front brake changes occurring through the first 20 stops of this schedule, but essentially stable output throughout the last 60 stops. If this test result is typical, the last 60 stops are unnecessary, and only serve to extend the length and cost of testing.

The four wheel disc version of the FWD vehicle was tested to both FMVSS 105 and FMVSS 135 proposed alternative 2 fade heating cycles. The results of the FMVSS 105 test are shown in Figures 12 and 13. As before, the changes in brake output are smaller in the second fade heating cycle of 105 than during the first. The proposed alternative 2 test results for this vehicle are shown in Figure 14. In the proposed alternative 2 test, the front brake output achieves a final value approximately equal to that of the second fade heating cycle of FMVSS 105, but higher than that produced in the first FMVSS 105 fade.

GM has also conducted extensive temperature testing related to various fade heating cycles for the FWD vehicle. A fully instrumented vehicle was evaluated in the first fade heating cycle of FMVSS 105, both heating cycles of FMVSS 135, and the fade heating cycle of R.88. Front and rear brake temperatures were measured in both the friction materials and the disc/drum braking member. The results of these tests are shown in Figures 15 through 22. It should be pointed out that these tests were run with instrumented torque wheels which have less offset and larger vent area than a nominal production wheel, and thus are expected to provide additional brake cooling. Thus, the absolute values of the temperatures reported here are expected to be lower in all cases than those that would be expected with a production wheel and a full wheel cover. However, experience has shown the effect of this difference is small on a relative basis, at least for short test cycles. Therefore the differences between the schedules should be unaffected.

For the FMVSS 105 heating cycle (Figures 15 and 16), the front brake temperature at the end of ten stops is approximately 400° C and at the seventh stop where the maximum change in front brake output was measured (see Figure 6) the front temperature is about 350° C (662°). Rear temperatures finish this fade heating cycle at about 200° C (392°).

The proposed alternative 1 fade heating cycle of FMVSS 135 results for this same vehicle are shown in Figures 17 and 18. In this case, the front and rear brake temperatures are higher, and remain at high levels for a longer period of time. For the semi-metallic friction materials used in the front brakes of this vehicle, our earlier analysis (Figure 11) shows that once front brake temperatures achieve about 300° C (572°) in this test, the changes in front brake output have occurred, and subsequent heating to over 400° C (752°) in the last 40 stops has no significant effect on output. Again, this test was run with large vent area instrumented torque wheels with small offset, and absolute temperature errors are expected to be most affected during an extended test like the proposed alternative 1 procedure. If substantial absolute errors exist in the GM temperature data, their impact is anticipated to be largest in this particular procedure. Should the agency decide to pursue proposed alternative 1 in spite of the GM recommendations to do otherwise, more testing would be necessary to understand the full impact of alternative 1 temperatures.

The proposed alternative 2 fade heating cycle of FMVSS 135 results are shown in Figures 19 and 20. For this particular test vehicle configuration, the temperatures achieved in the front and rear brakes are quite similar to those developed in the first fade heat cycle of FMVSS 105.

The temperatures developed in the fade heating cycle of R.88 are shown in figures 21 and 22. For this particular vehicle configuration, the front and rear temperatures are roughly equivalent to FMVSS 105 through the first 7 stops, but in R.88 level out at about 300° C for the fronts and approximately 150° C (302°) for the rears, while temperatures continue to increase in the FMVSS 105 first fade heating cycle.

Two important points can be made from the data reviewed so far. The first is that the fade heating cycles in FMVSS 105 (first fade), R.88, and FMVSS 135 proposed alternative 2 are all roughly equivalent through about seven stops, at which point the front brake output changes have all been achieved. Subsequent heating of the brake elements markedly affects only the asbestos friction materials on the front brakes. Subsequent heating of the rear brakes does produce additional minor changes in output, but with the focus of FMVSS 135, R.88, and ECE R13 all aimed at front axle limited brake balance, the changes in the front brake output are the most significant. The second important point to make is that the peak temperatures developed in the fade heating cycles are not strongly related to the magnitude or direction of change in either front or rear brake output. Comparisons of various fade heating cycles on the basis of peak temperature are probably misleading, and a more appropriate basis needs to be used. Based on substantial GM test history, a "time at temperature", or equivalently, an "energy per unit time" basis should be adopted for relative comparisons of fade heating cycles.

Beyond the question of comparisons between various certification test procedures, a more relevant issue is to identify what level of energy it is reasonable to expect that vehicle braking systems will encounter during their first exposure to the demands simulated by these fade test cycles. To address this question, additional GM testing of the FWD vehicle was conducted at Pikes Peak in Colorado. Using a fully instrumented vehicle, three test runs down the mountain according to both the worst case GM test procedure and a simulated 90th percentile customer procedure were made for comparison to the fade heating cycles of FMVSS 105, FMVSS 135 proposed alternatives 1 and 2, and R.88. Using numerically integrated torque wheel data gathered at a 40 hz sampling rate, the actual energy dissipated in the vehicle's braking system was measured for each case.

The stringency of the Pikes Peak tests relative to customer driving can be appreciated only with some additional perspective. The worst case driving scenario for customers is a GVW descent of Pikes Peak, the highest mountain peak in North America on which the public is permitted to operate motor vehicles. Assuming a customer might actually descend the mountain with the vehicle loaded to GVWR, this loading condition is used in GM tests. Further, it is assumed that the customer will disregard all warning signs and instructions to the contrary, and choose to descend the mountain with the transmission in high or drive gear (not overdrive) and rely primarily on the vehicle's brakes alone to control descent speeds. Making all these assumptions, one arrives at the GM procedure for evaluating vehicle braking systems, referred to as the PP-GM procedure.

Based on surveys of customers actually descending Pikes Peak, GM has also developed a "customer schedule" (referred to as PP-ACT) which requires a GVWR descent of the mountain in one gear selection lower than that used in the PP-GM procedure. This PP-ACT procedure represents customer instructions for gear selection. Overall, the PP-ACT schedule is believed to represent severity higher than the 90th percentile customer since most traverse the mountain at vehicle weights less than GVWR. In either schedule, the vehicle's brake system receives only a prior 200 stop FMVSS 105 burnish, and such service as is necessary to ascend the mountain prior to testing.

Given this background regarding the Pikes Peak schedules used by GM, it is reasonable to ask how these compare to the fade heating schedules used in FMVSS 105, FMVSS 135, and R.88. A total specific kinetic energy comparison can be made from the difference of squares of vehicle velocity, in either ft-lbf/lbm/mile or ft-lbf/lbm/minute. Additionally, the measured specific brake kinetic energy can be determined, based on actual vehicle torque wheel tests and using a numerical integration technique. On flat track schedules these two energy measurements are expected to differ only as a result of driveline and aerodynamic effects. However, on actual mountain descents specific brake kinetic energy is expected to be higher than specific kenetic energy. This can be understood if one recognizes that in addition to the velocity differences, the mountain descent requires the vehicles braking system to convert the potential energy of the vehicle at the top of the mountain to kinetic energy, i.e., the vehicle could descend the mountain at a constant velocity by dragging the brakes and no kinetic energy resulting from velocity change would result in spite of the fact that the vehicle's braking system would obviously have done considerable work.

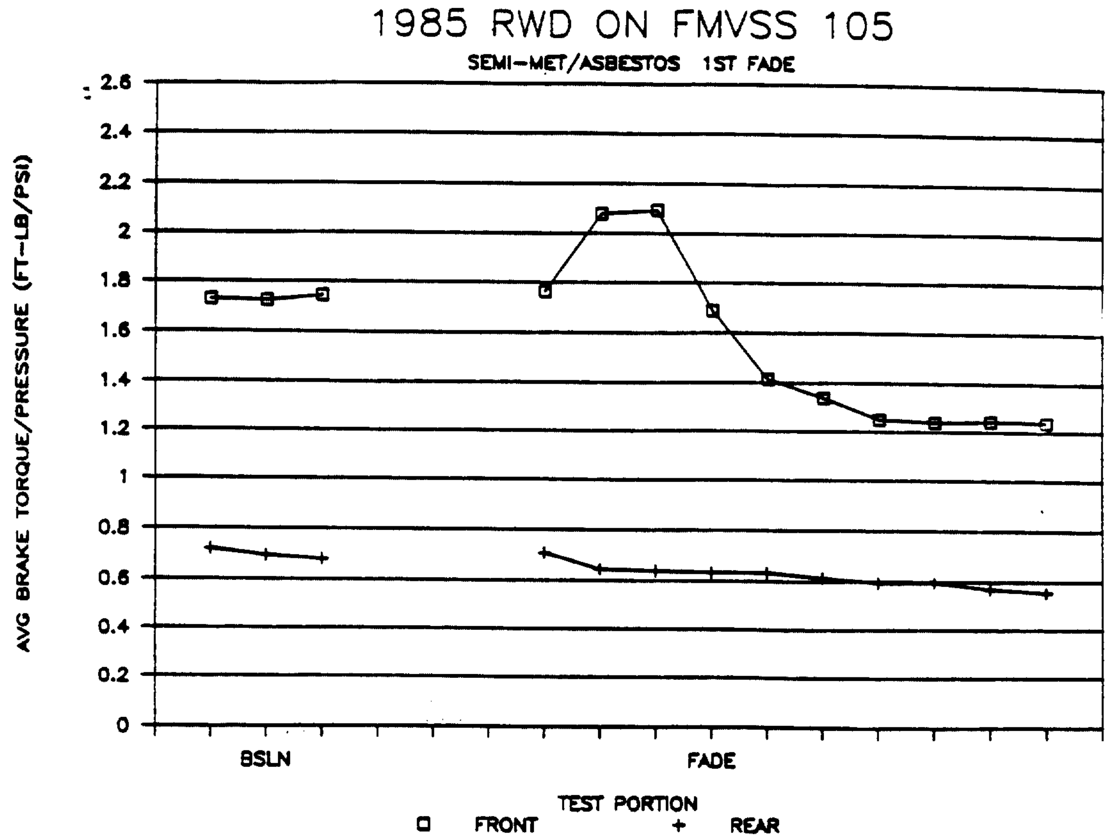
The results of this comparison on the basis of kinetic energy per mile is shown in Figure 23, where we see that on a mileage basis all the fade heat cycles being reviewed in this section exceed that encountered by the 90th percentile customer at Pikes Peak, with only R.88 being a reasonable approximation.

A similar comparison is shown in Figure 24 on a basis of energy per unit time. Here again we see all four fade heating cycles well in excess of that expected for the 90th percentile customer at Pikes Peak and R.88 more demanding than either FMVSS 105 or FMVSS 135 proposed alternative 1. Proposed alternative 2 of

FMVSS 135, producing the highest kinetic energy per mile, is clearly out of line with the others, and should be eliminated from further consideration on this basis alone.

This data has been replotted for the relative energy dissipated in the brake system in Figures 25 and 26 to facilitate quantitative comparisons. This is the same information shown earlier, but in a more convenient format. On the basis of real vehicle test data, all of the fade heating cycles being offered are clearly in excess of that likely to be encountered by the customer. In each case, these fade heat cycles are run on relatively unused brake linings, and with the exception of FMVSS 105's second fade, prior to any previous exposure to such schedules. The fade exposure for any of the FMVSS cycles as measured in these tests is more severe than would be encountered by customers.

Given either the per mile or per unit time basis for comparison, only the fade heat cycle of R.88 can be considered reasonable relative to actual customer experience. On either basis, the R.88 schedule is in excess of the actual customer usage, but clearly the most nearly representative. All other fade heating cycles are clearly more stringent than necessary.



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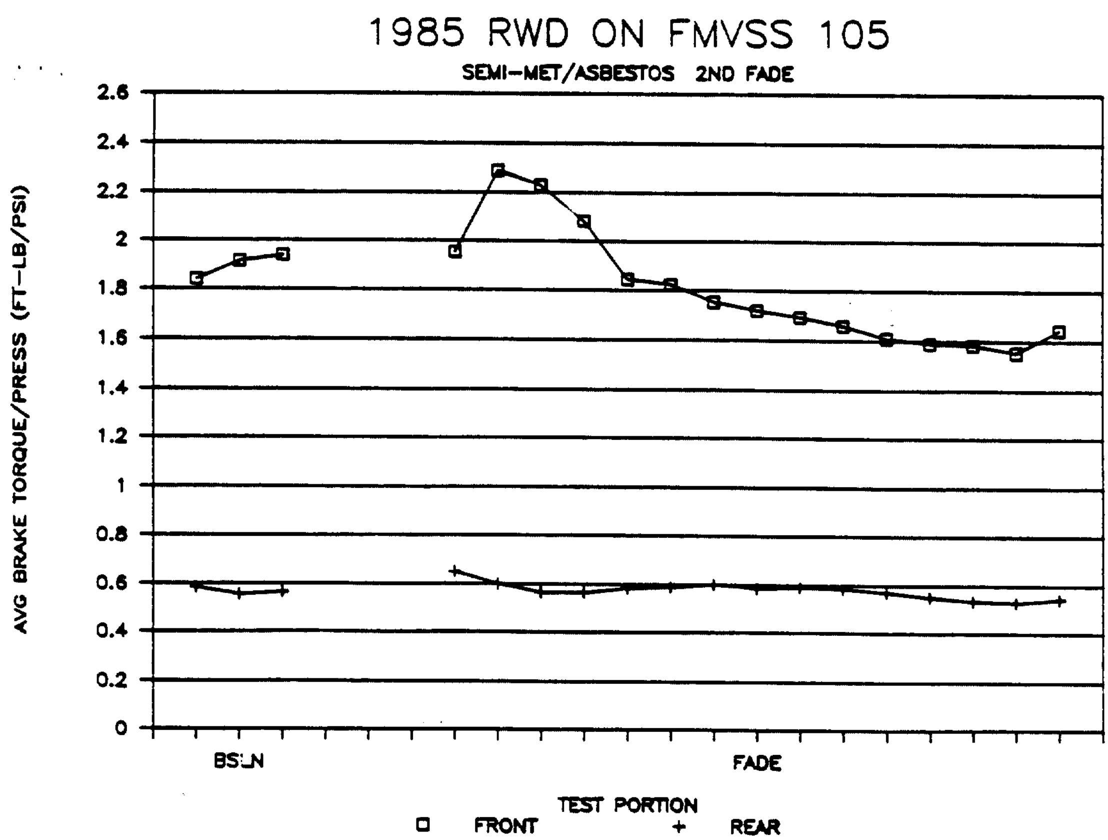

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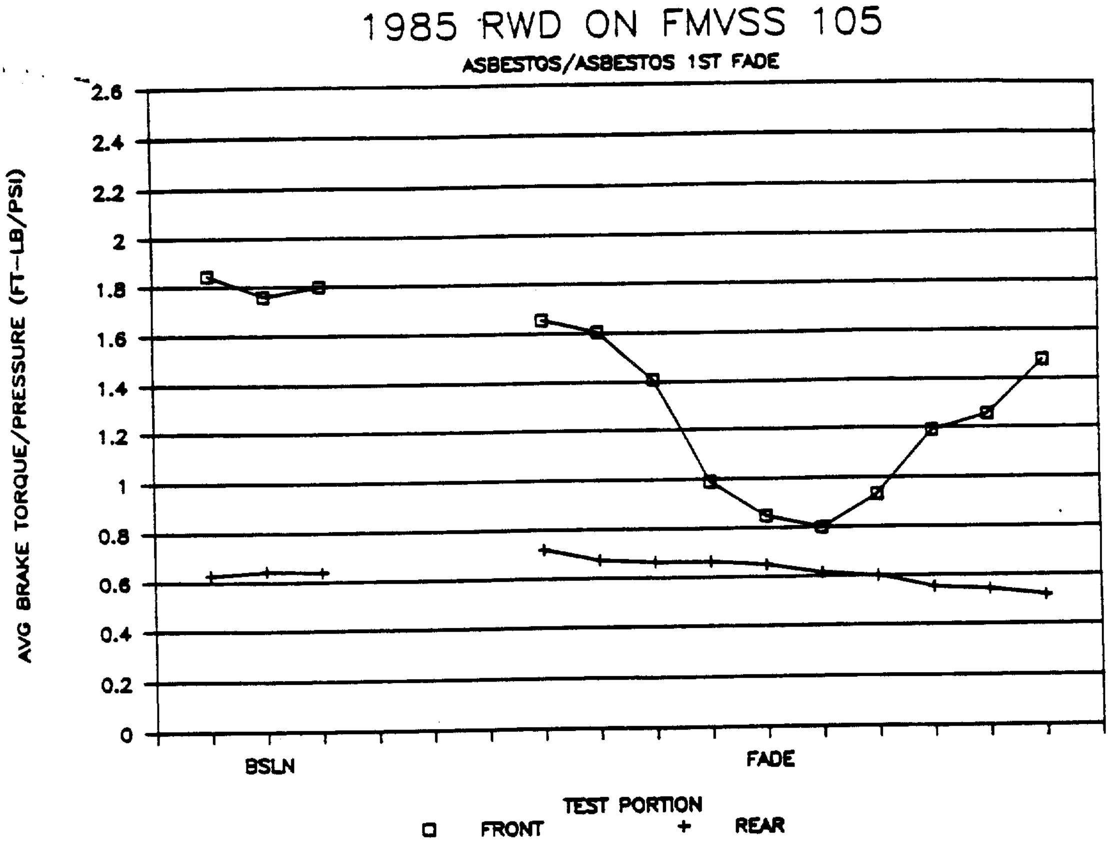

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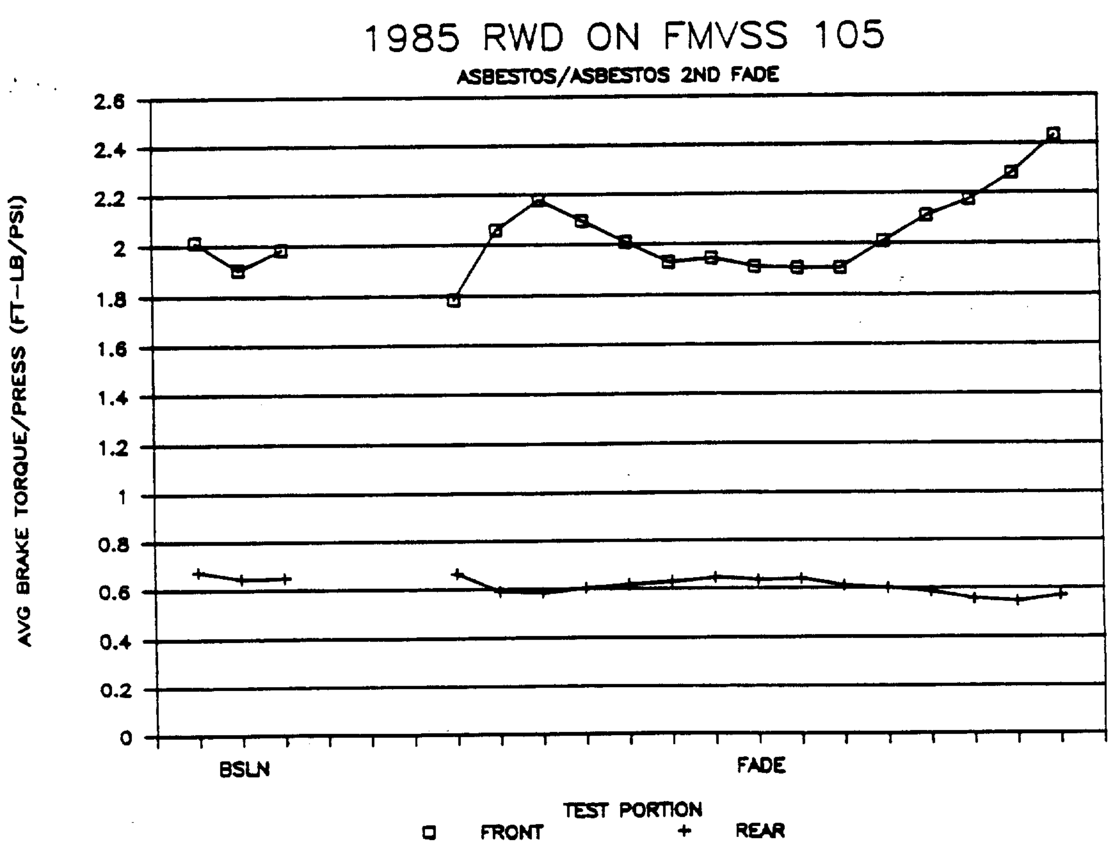

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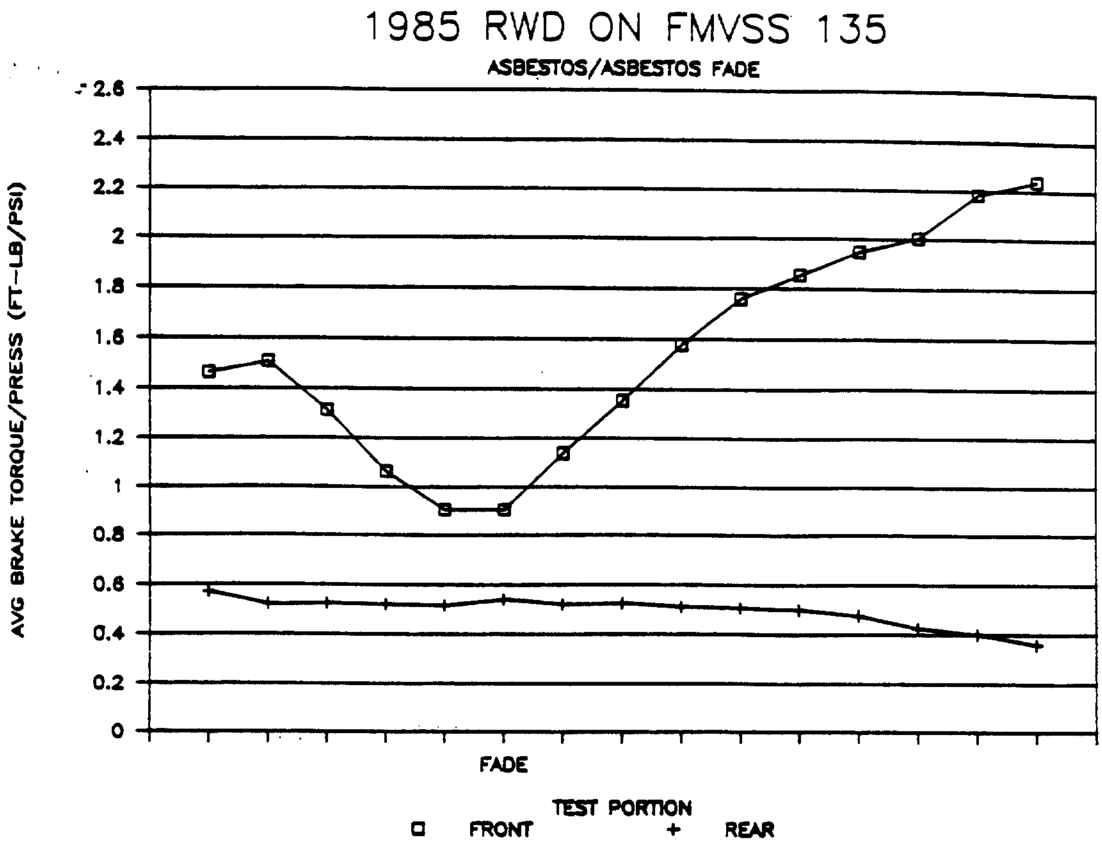

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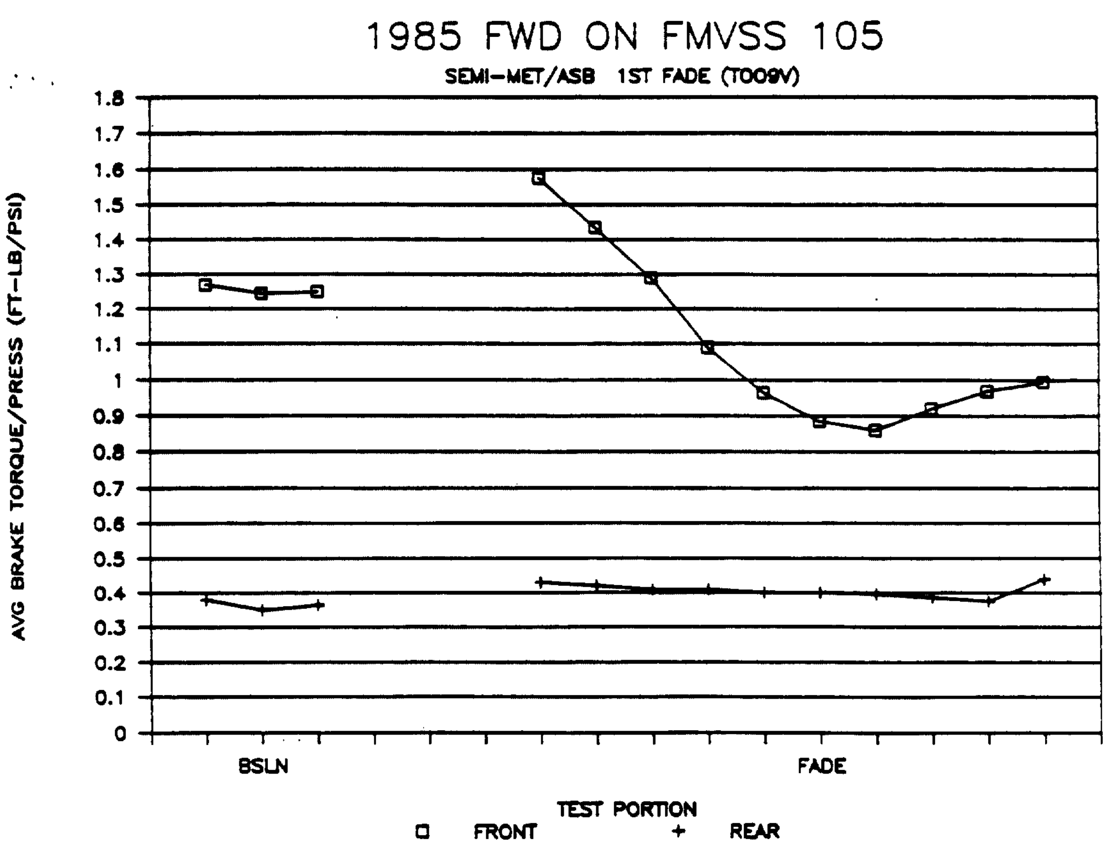

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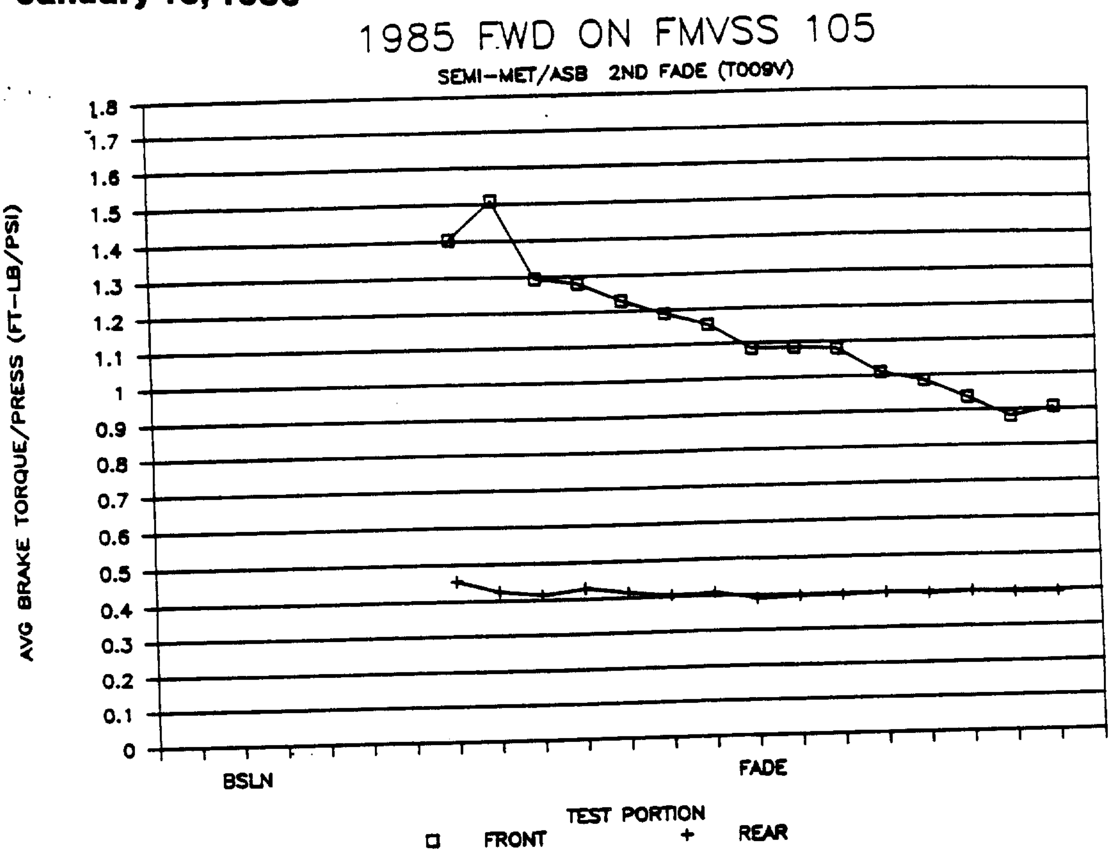

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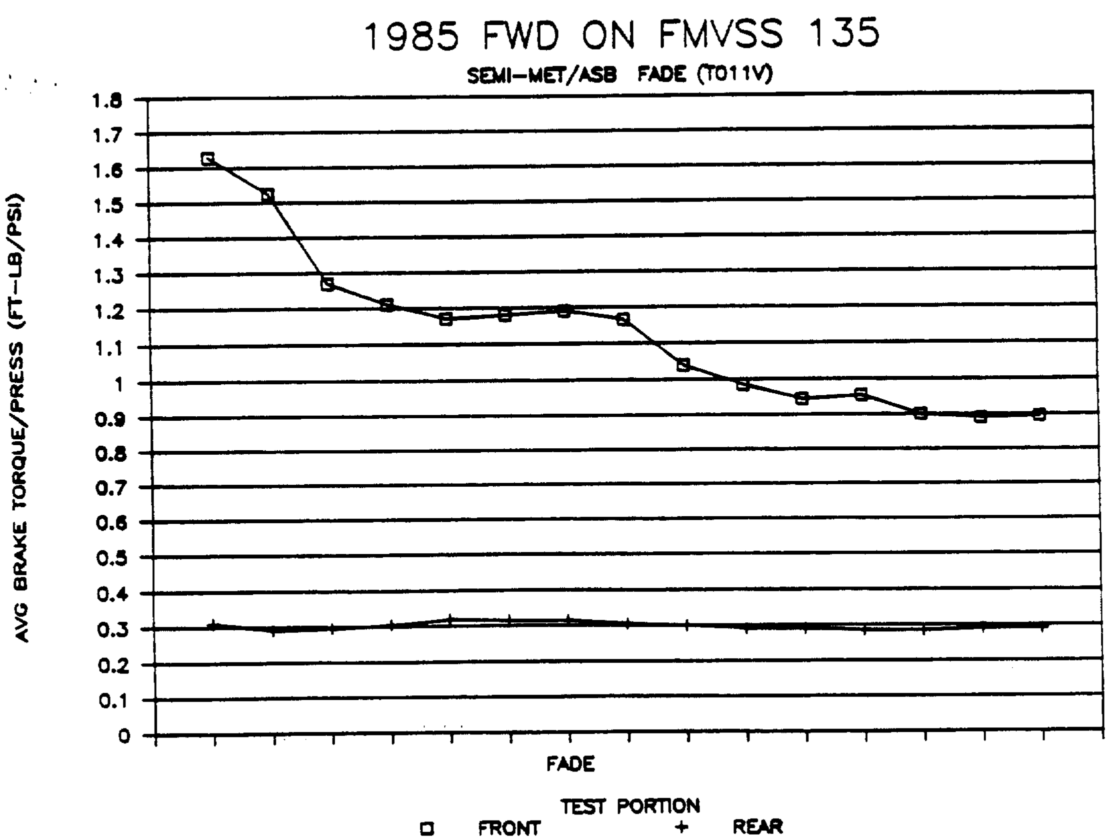

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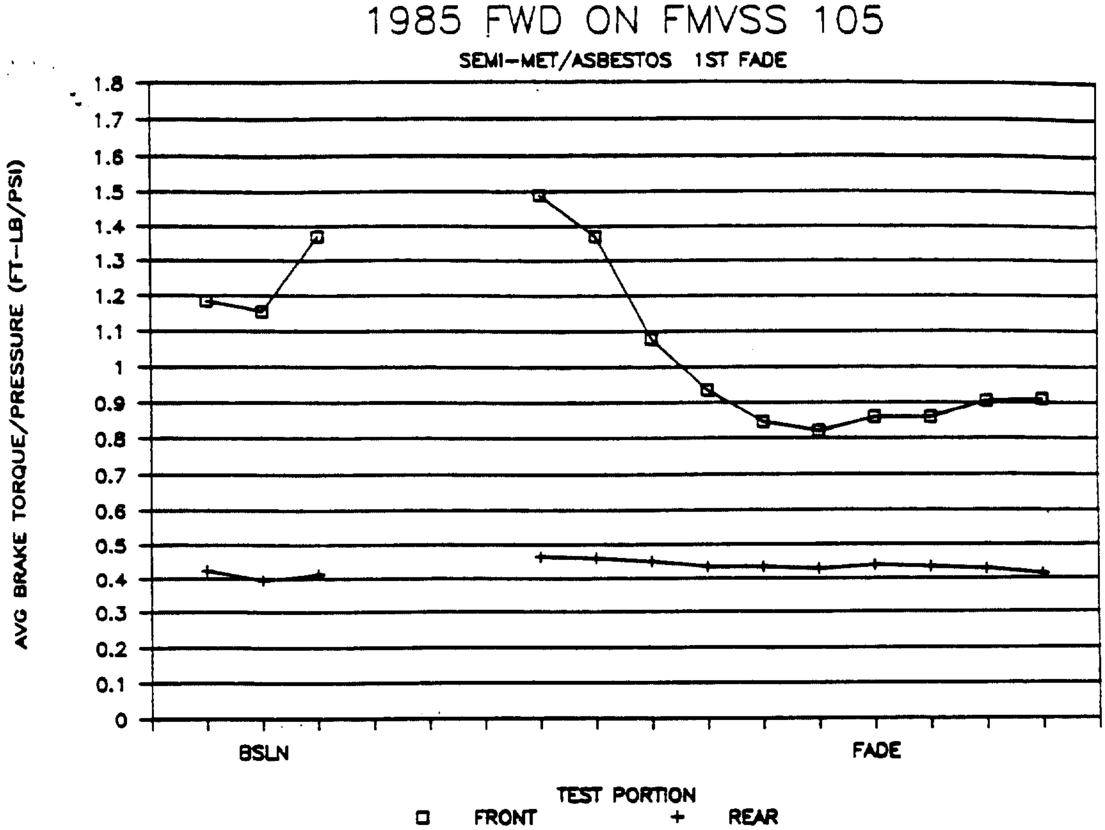

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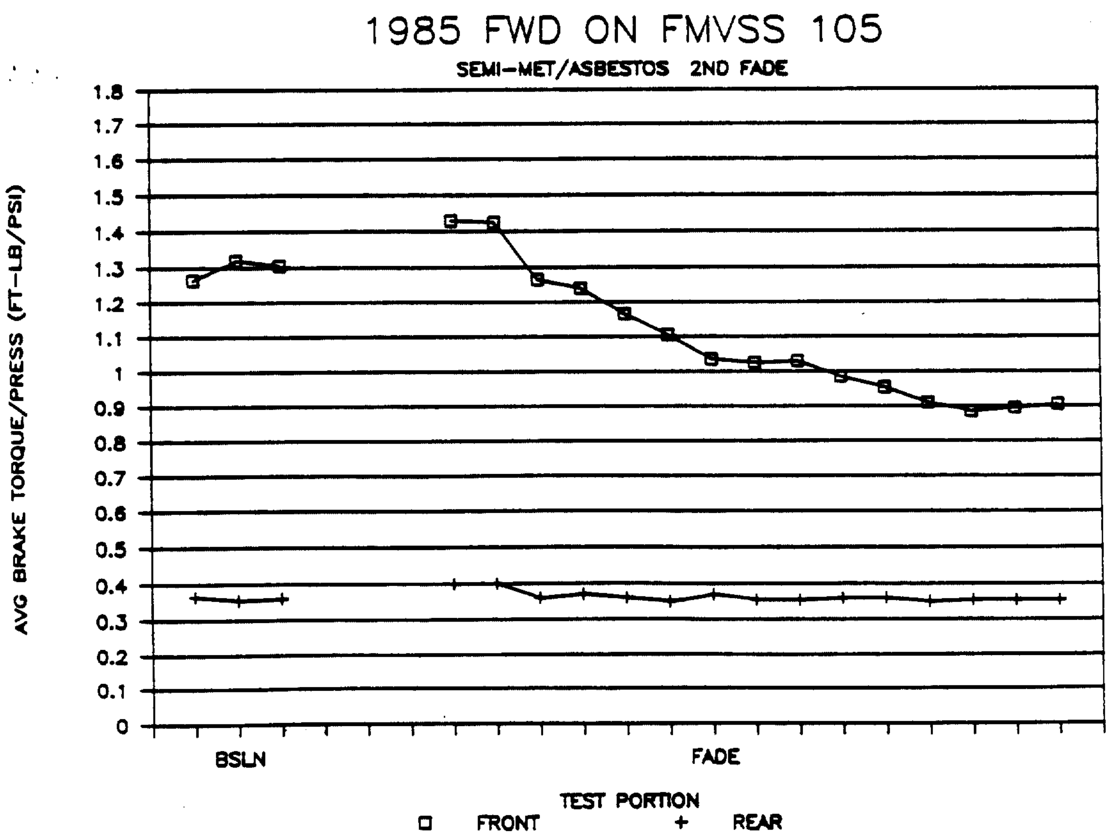

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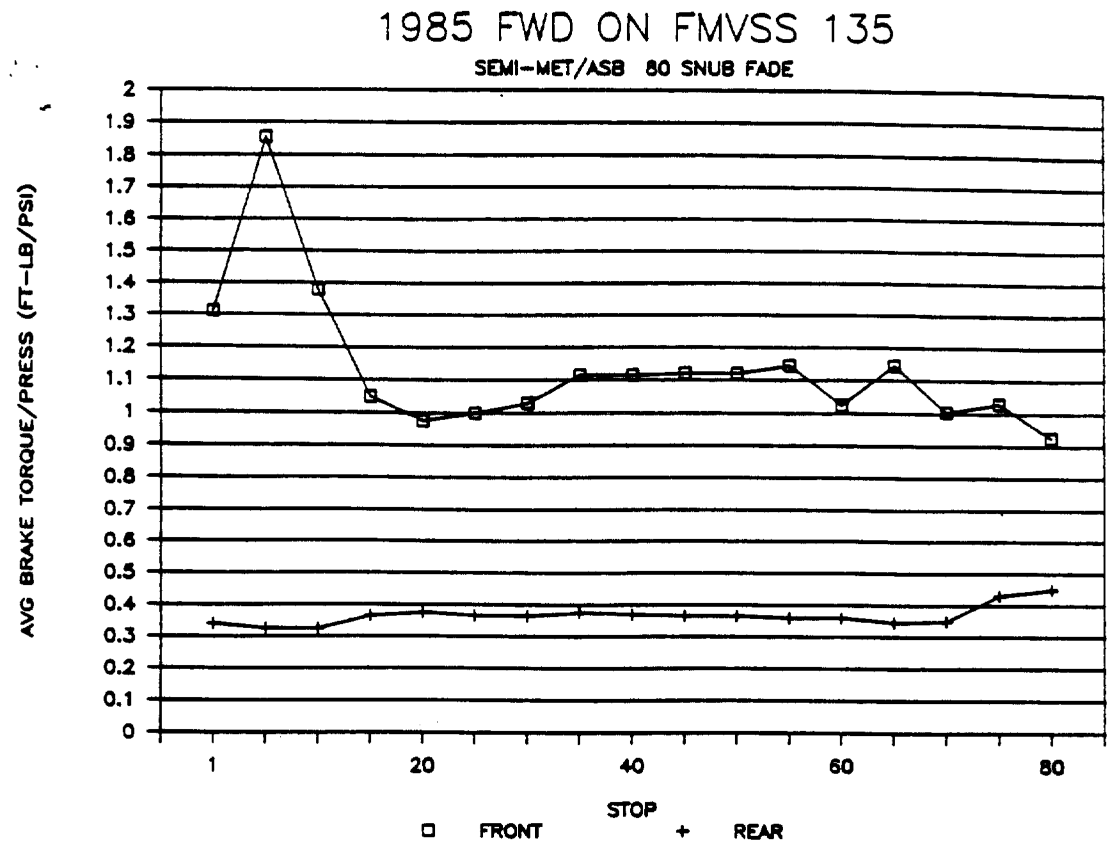

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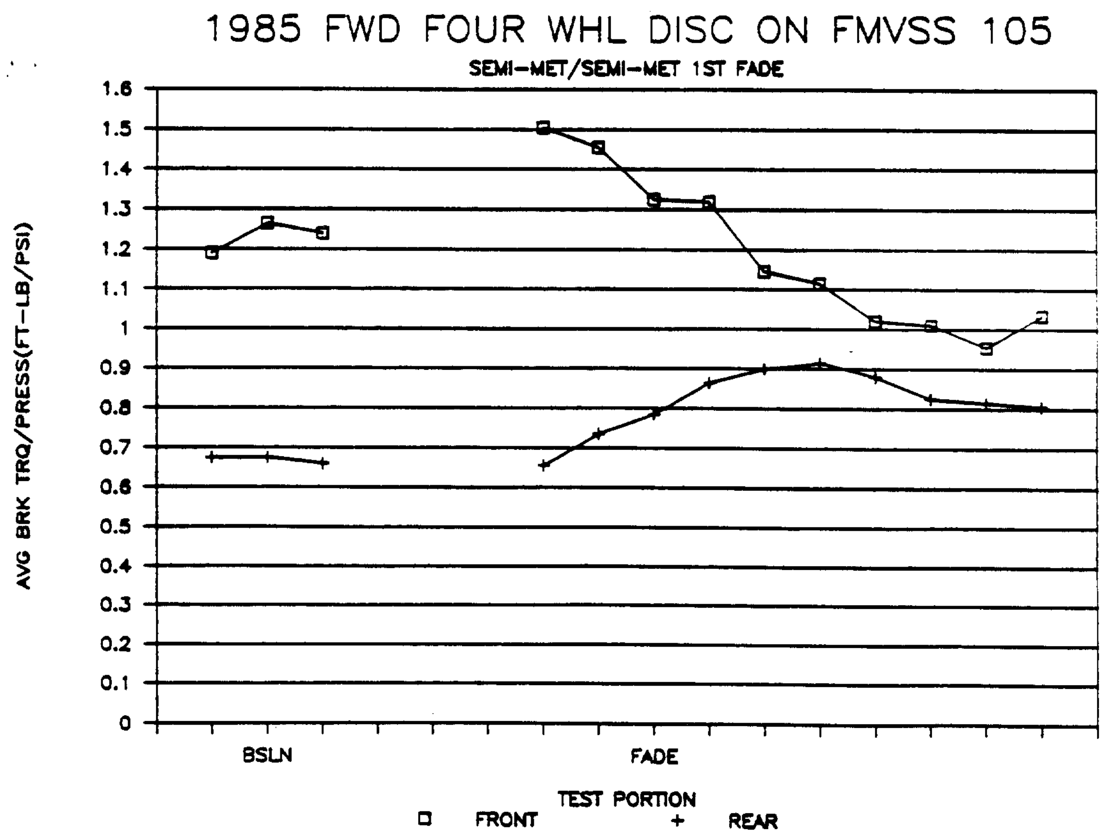

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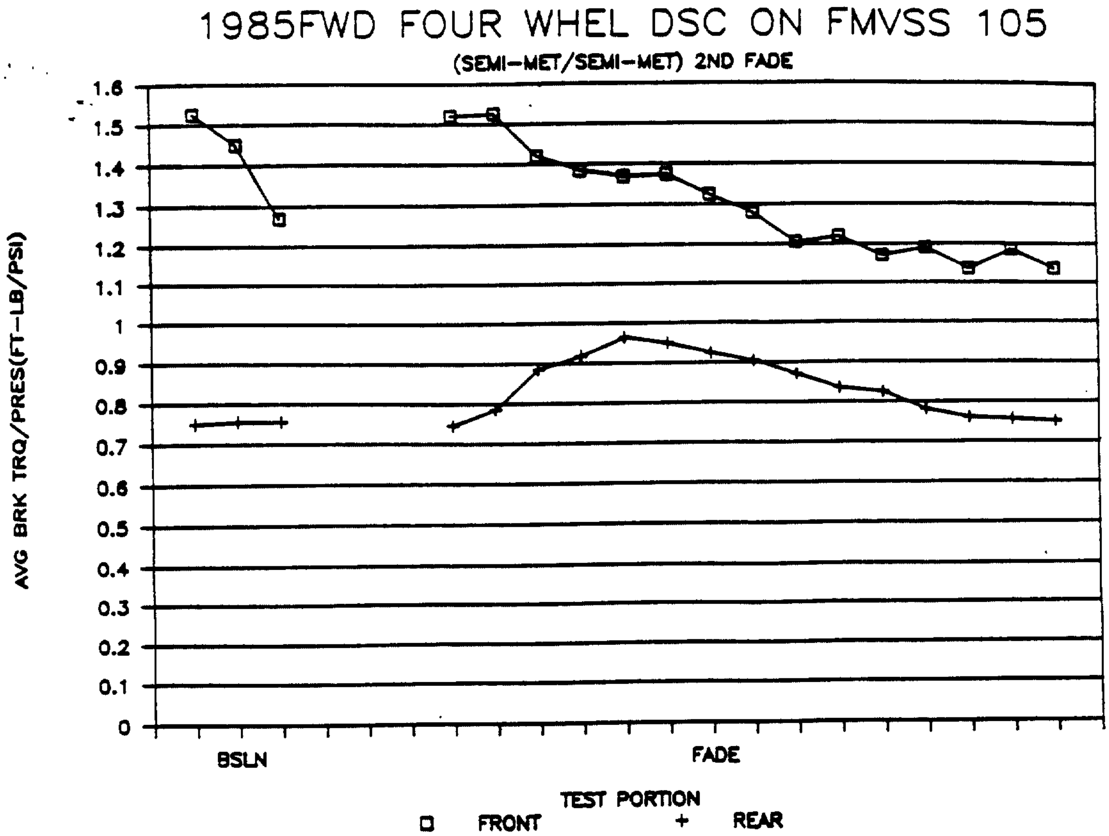

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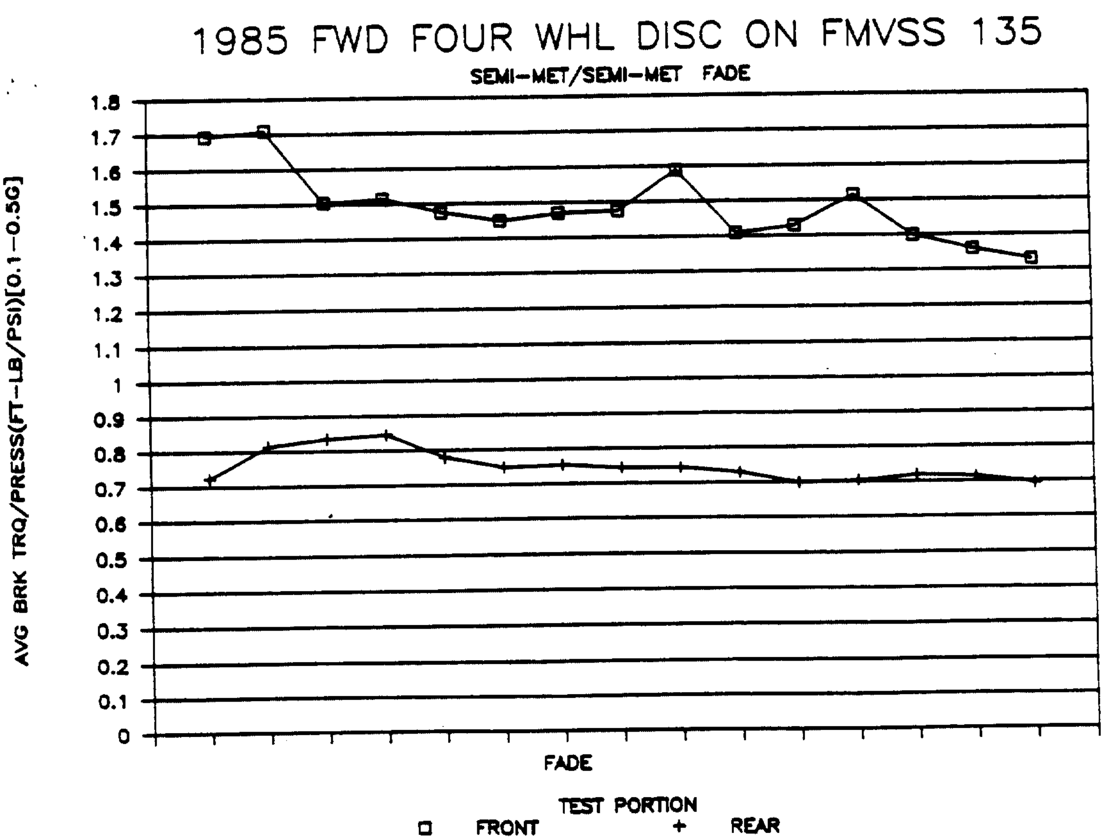

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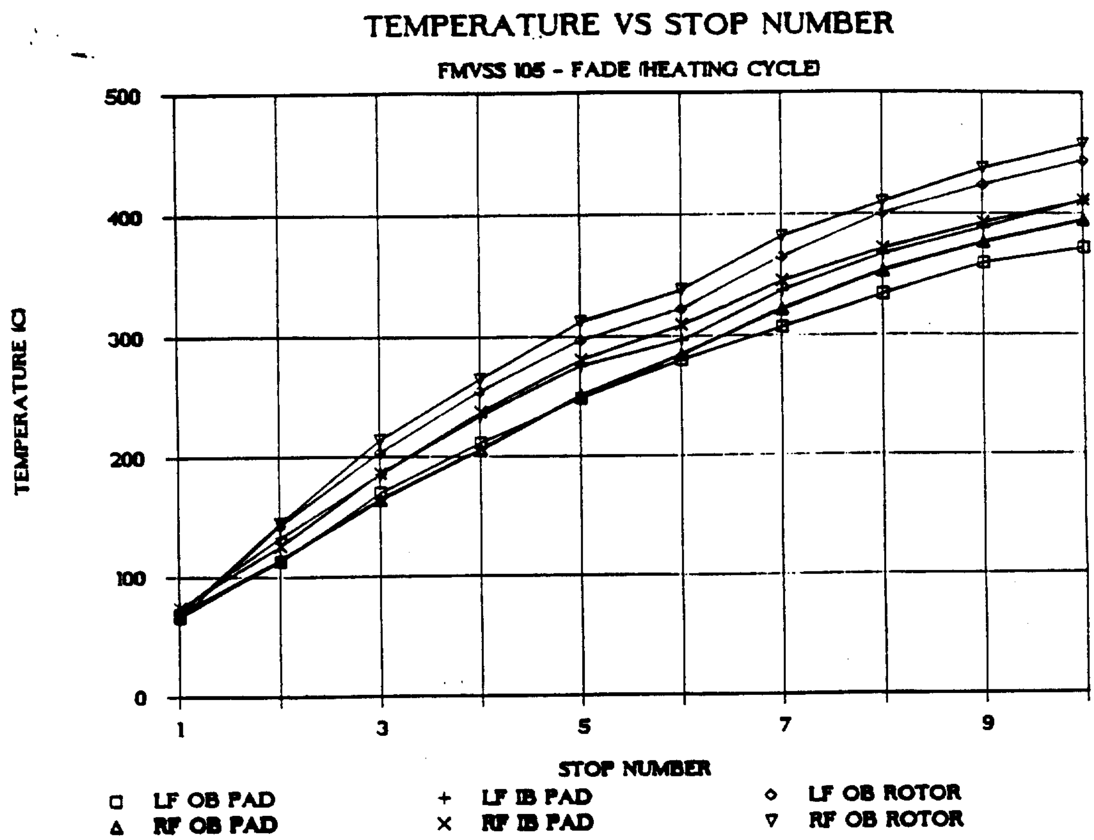

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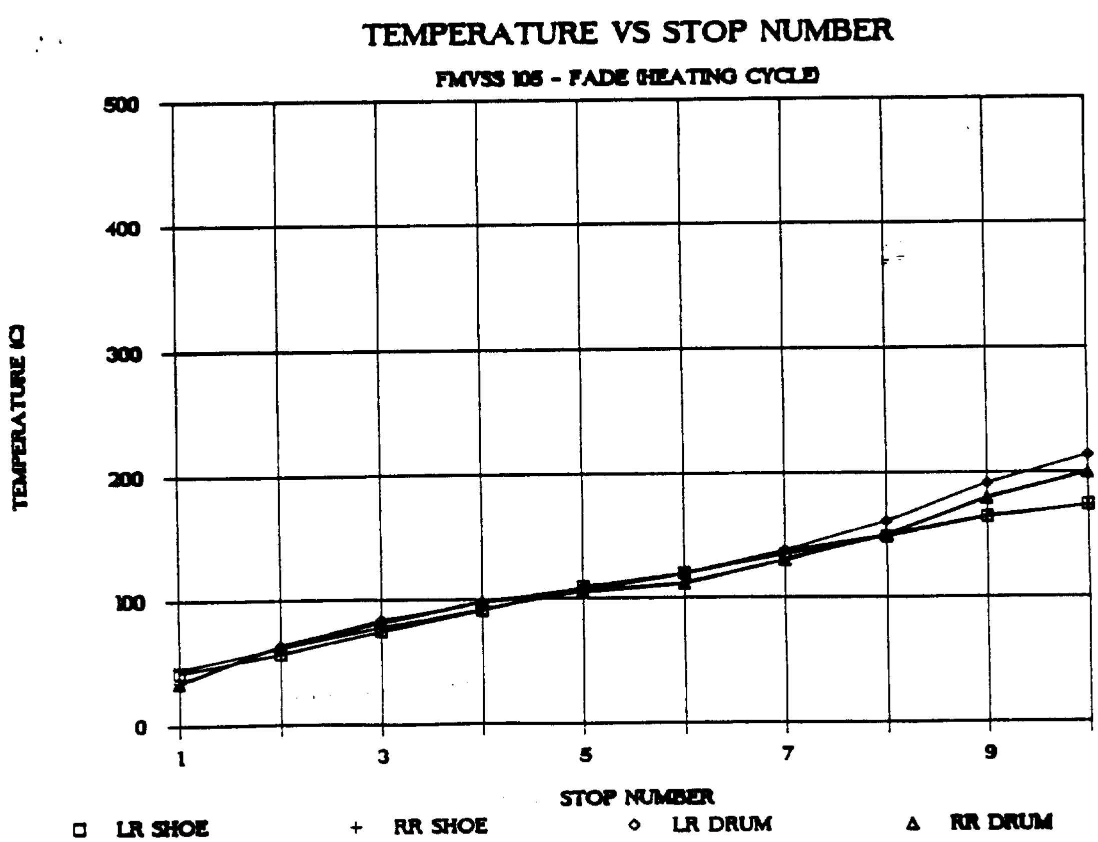

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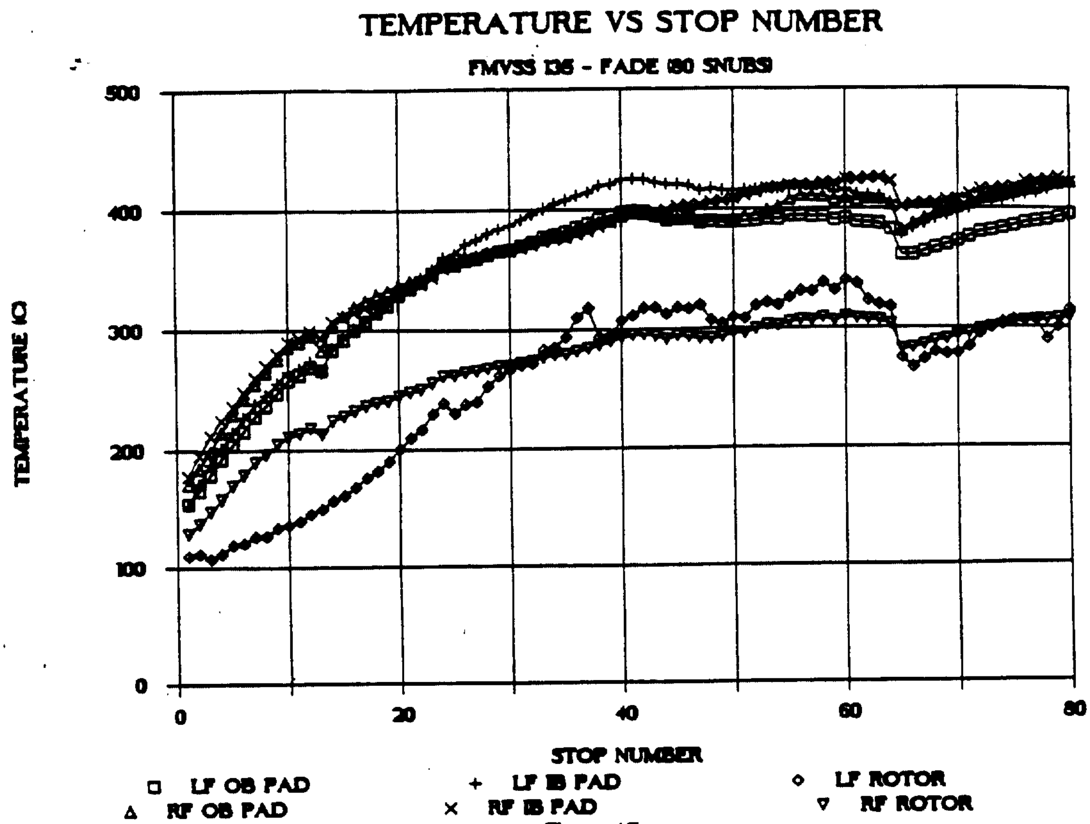

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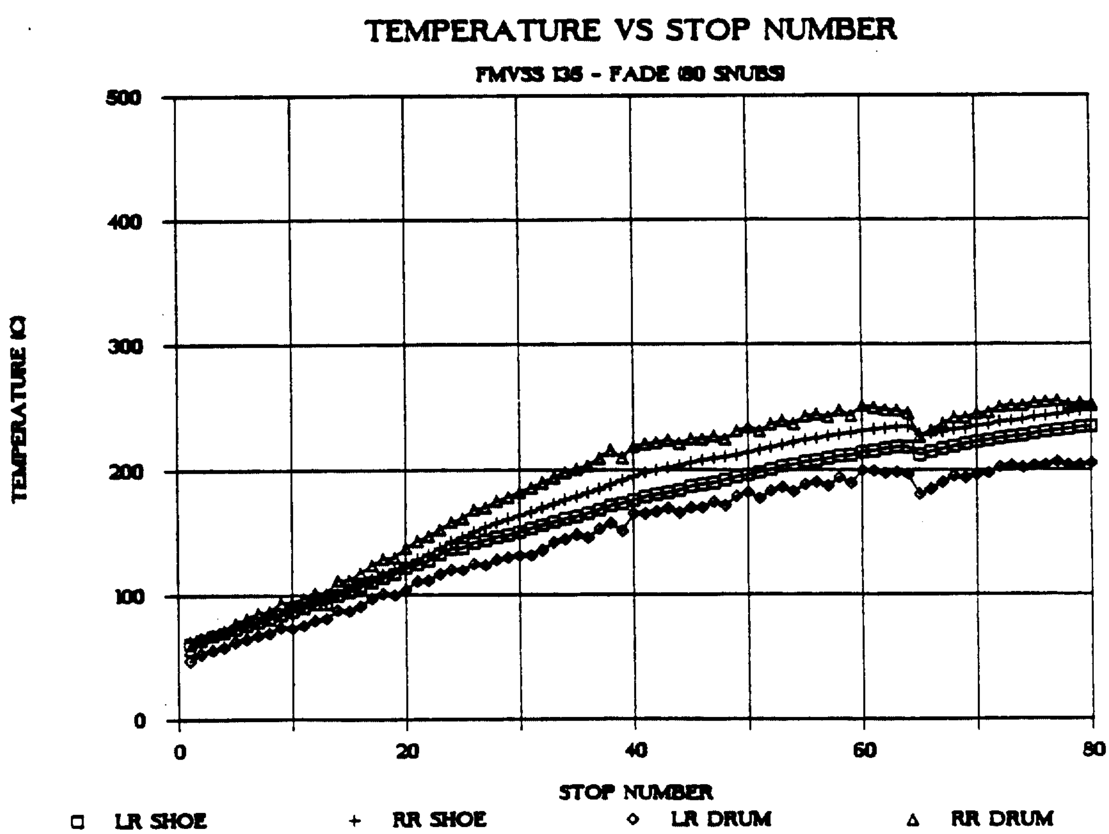

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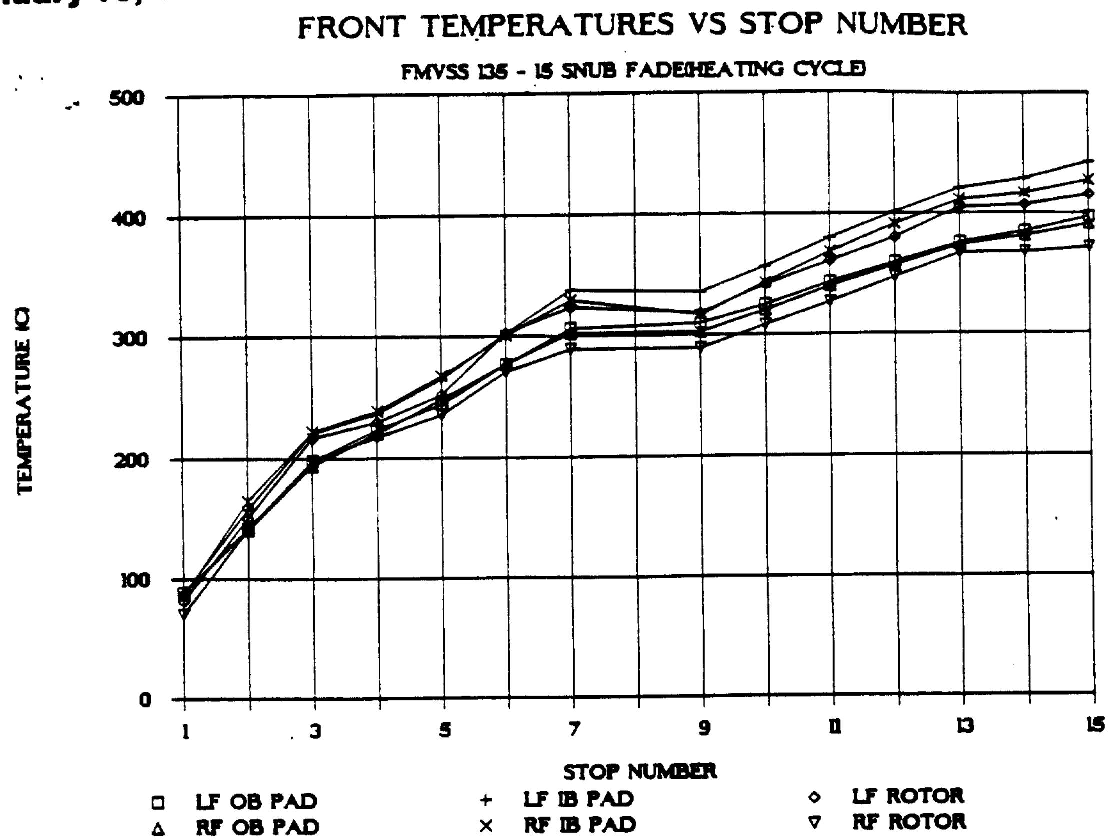

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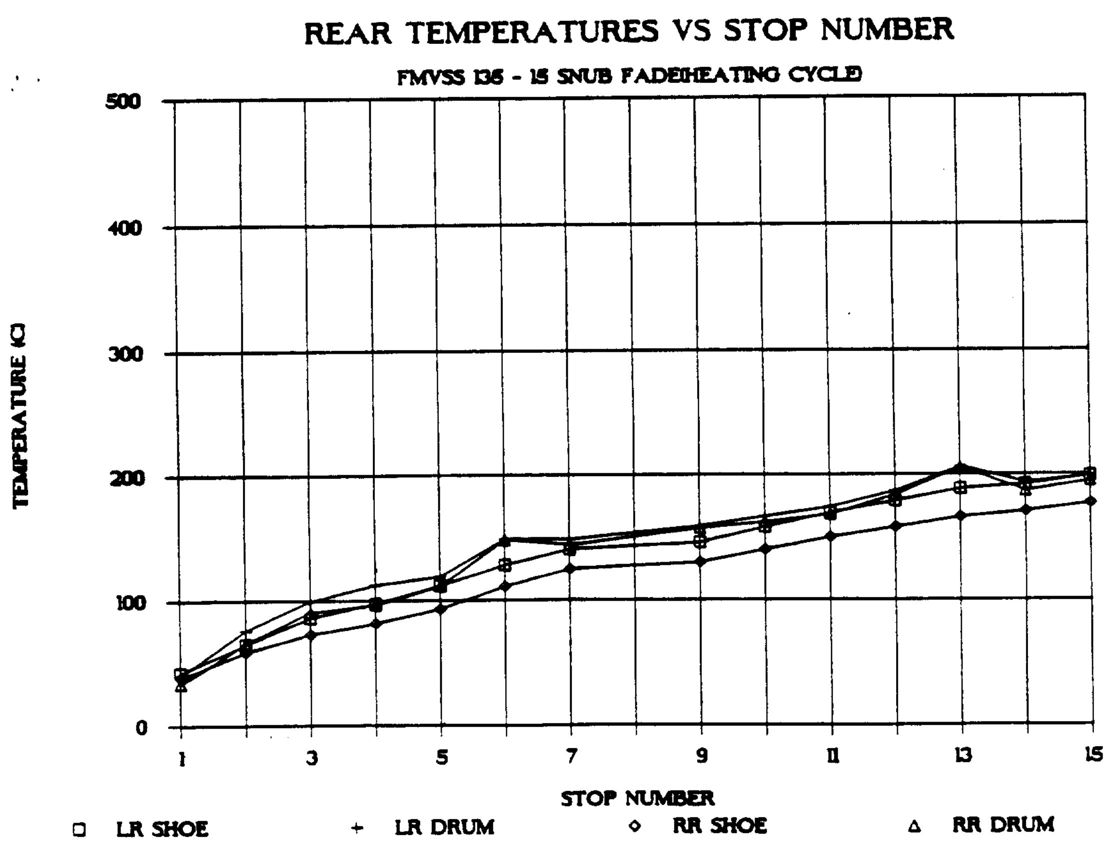

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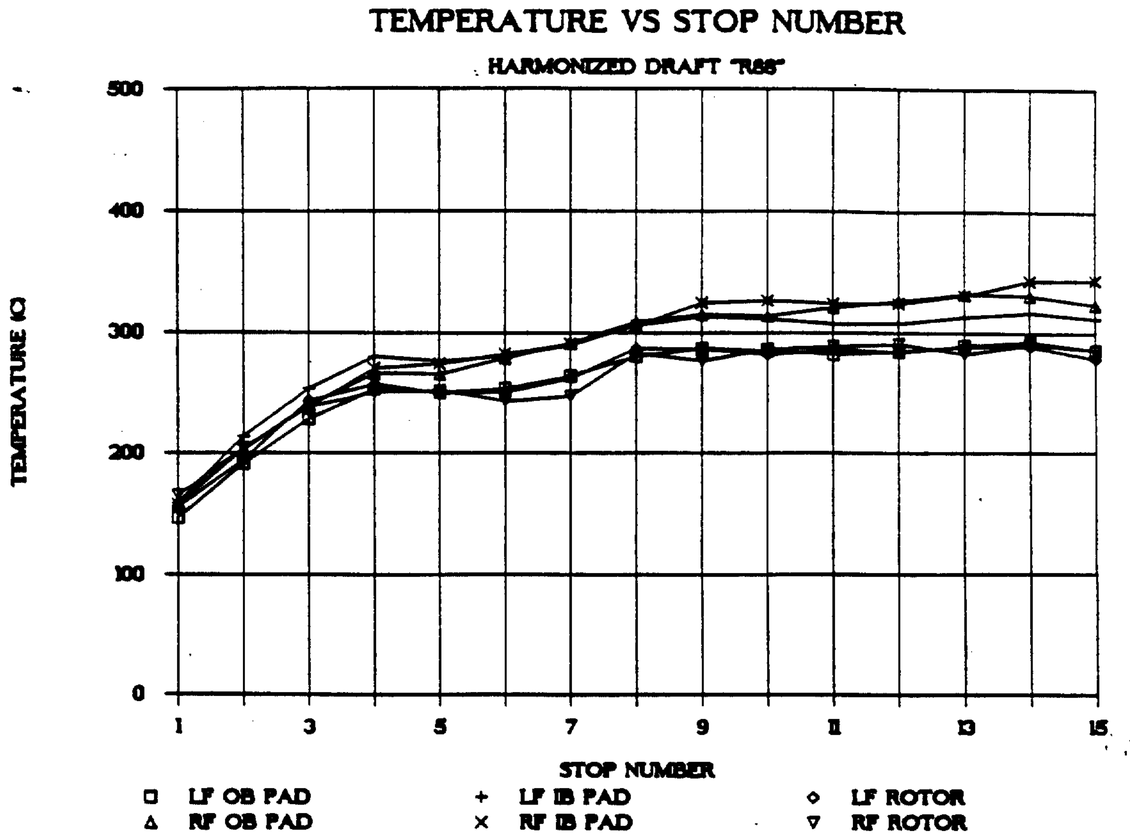

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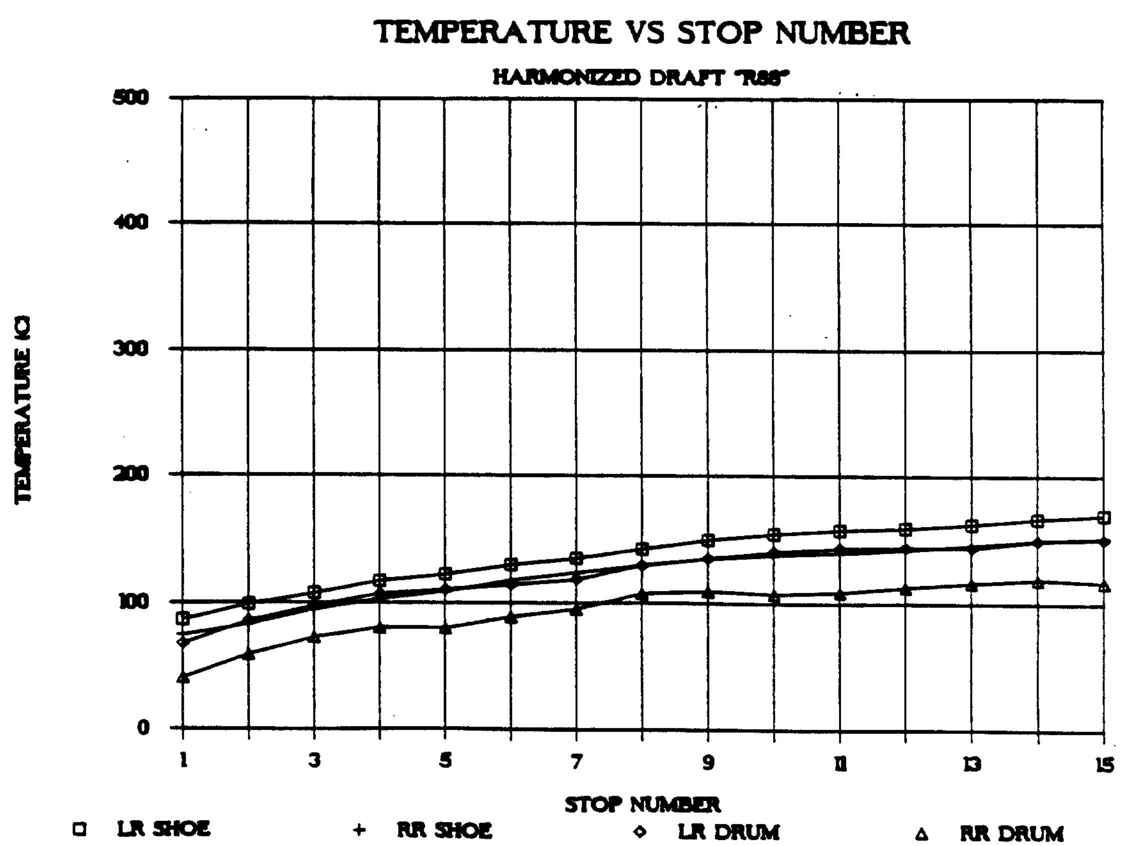

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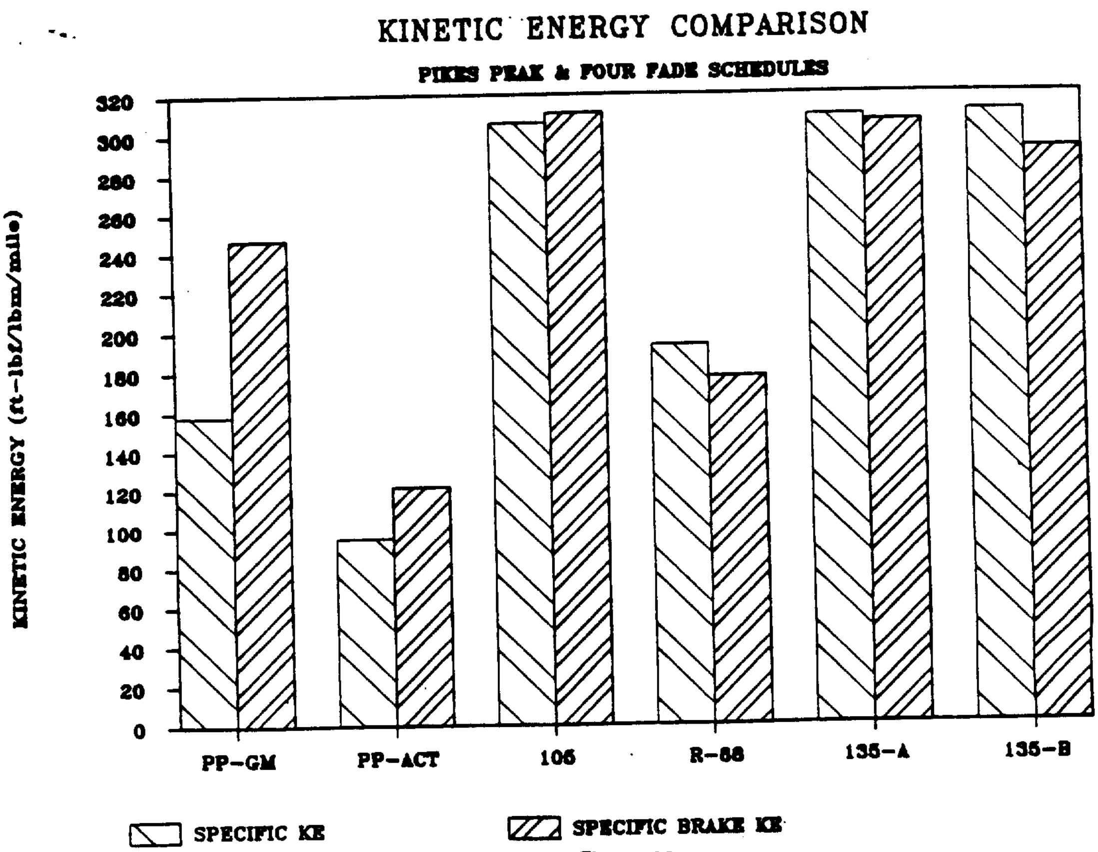

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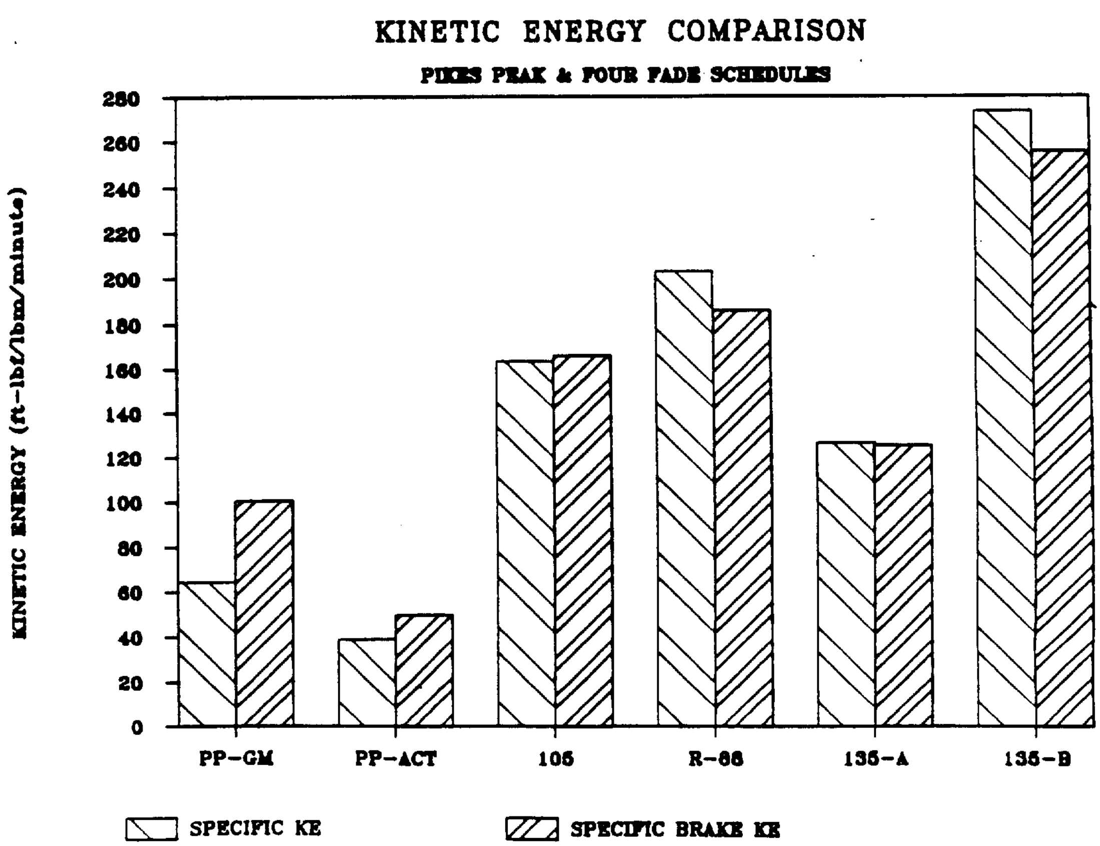

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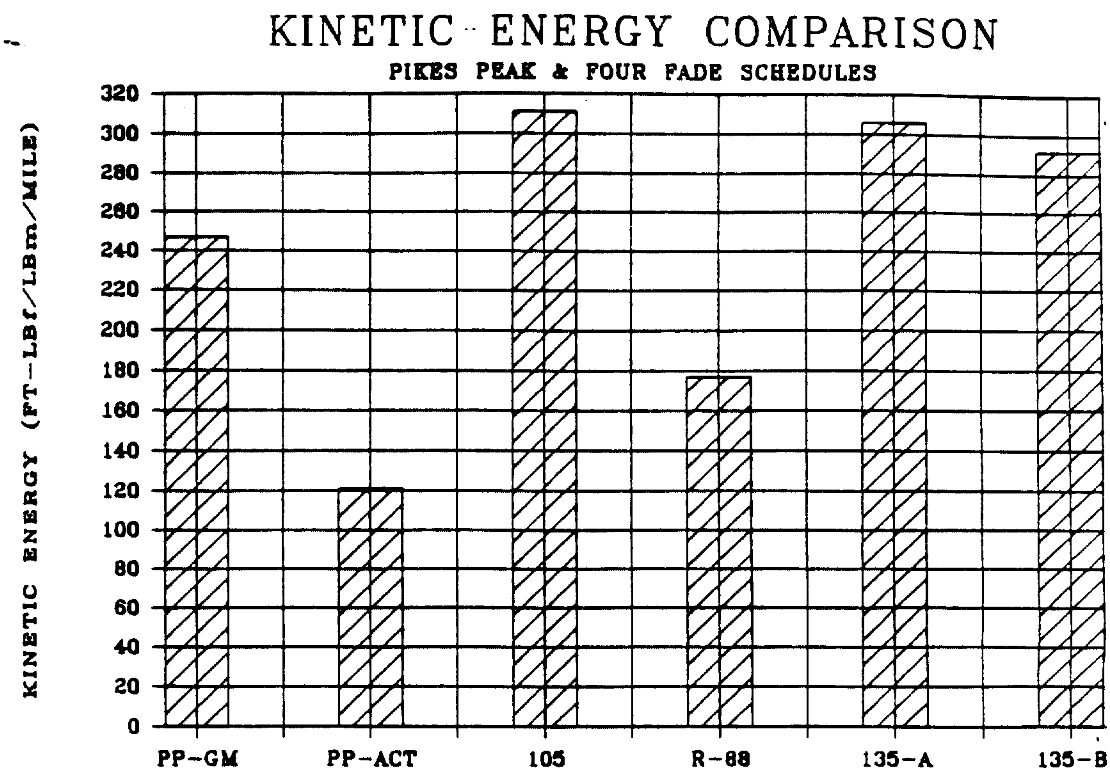

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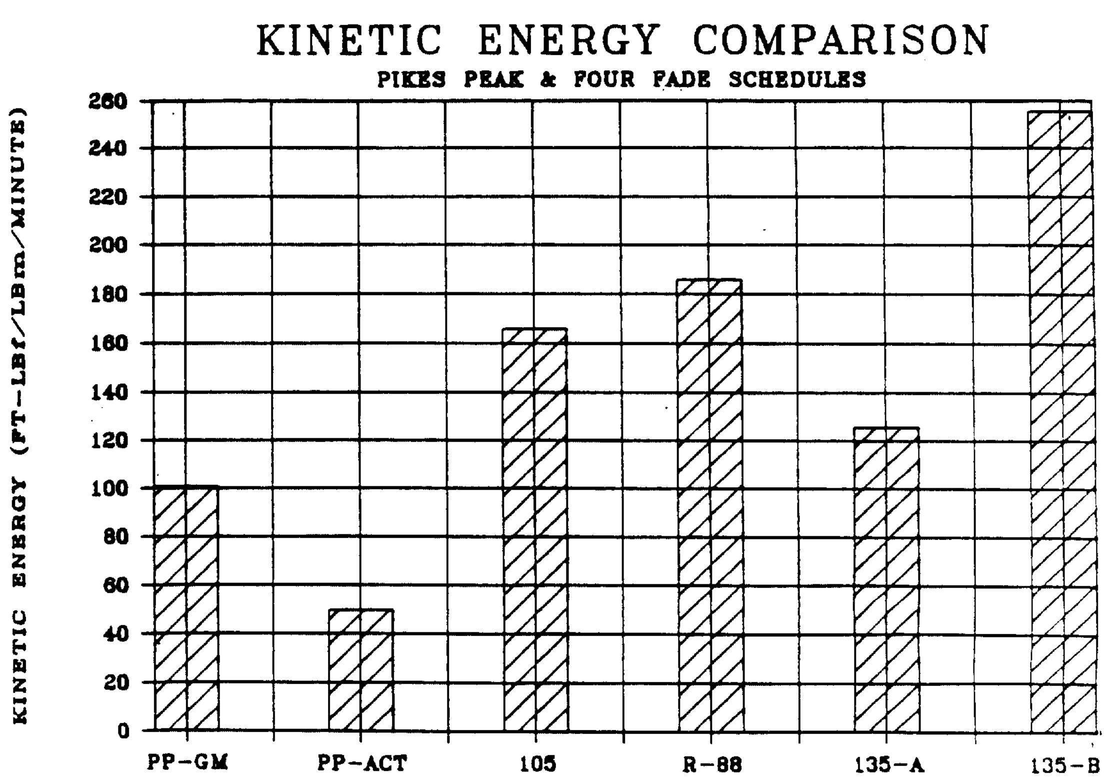

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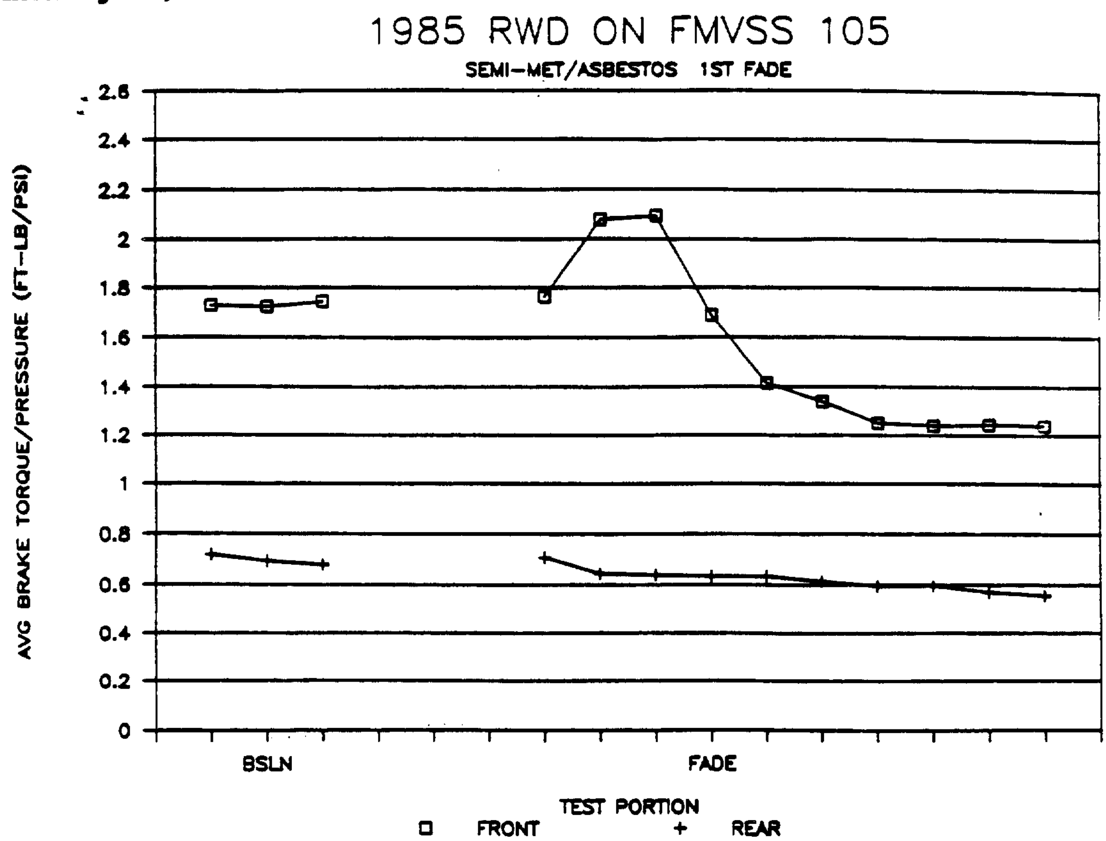

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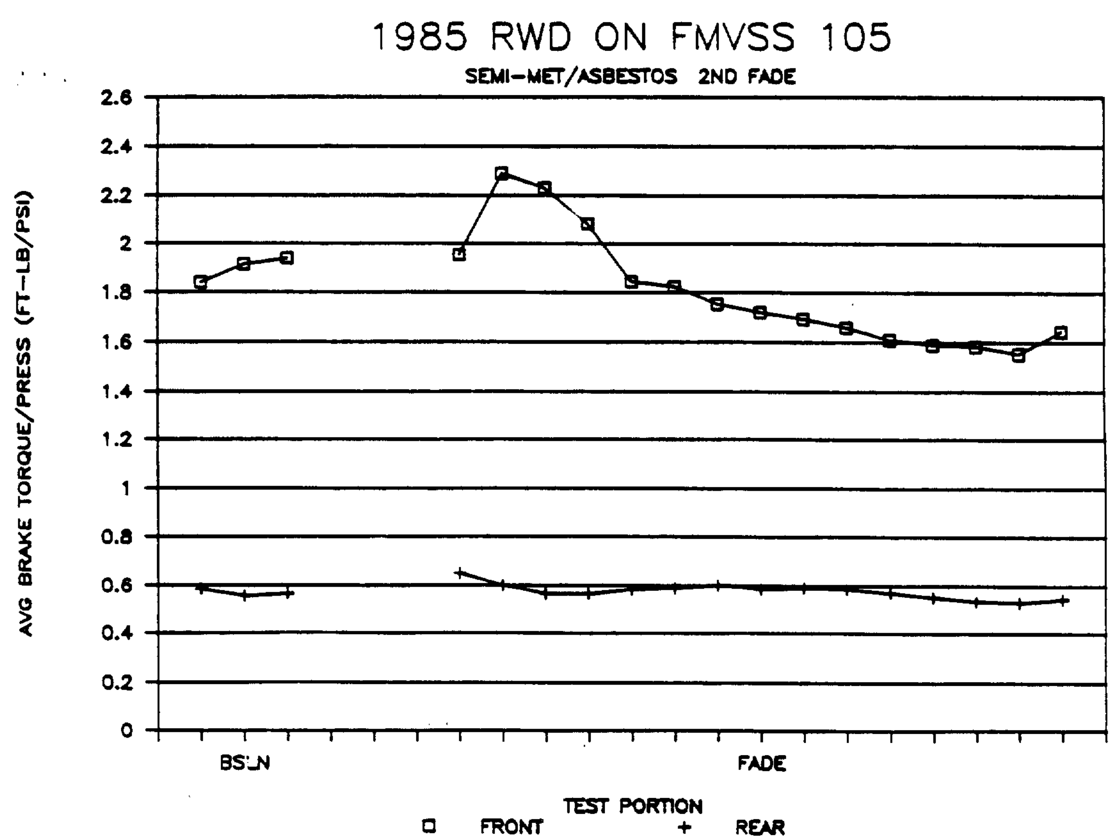

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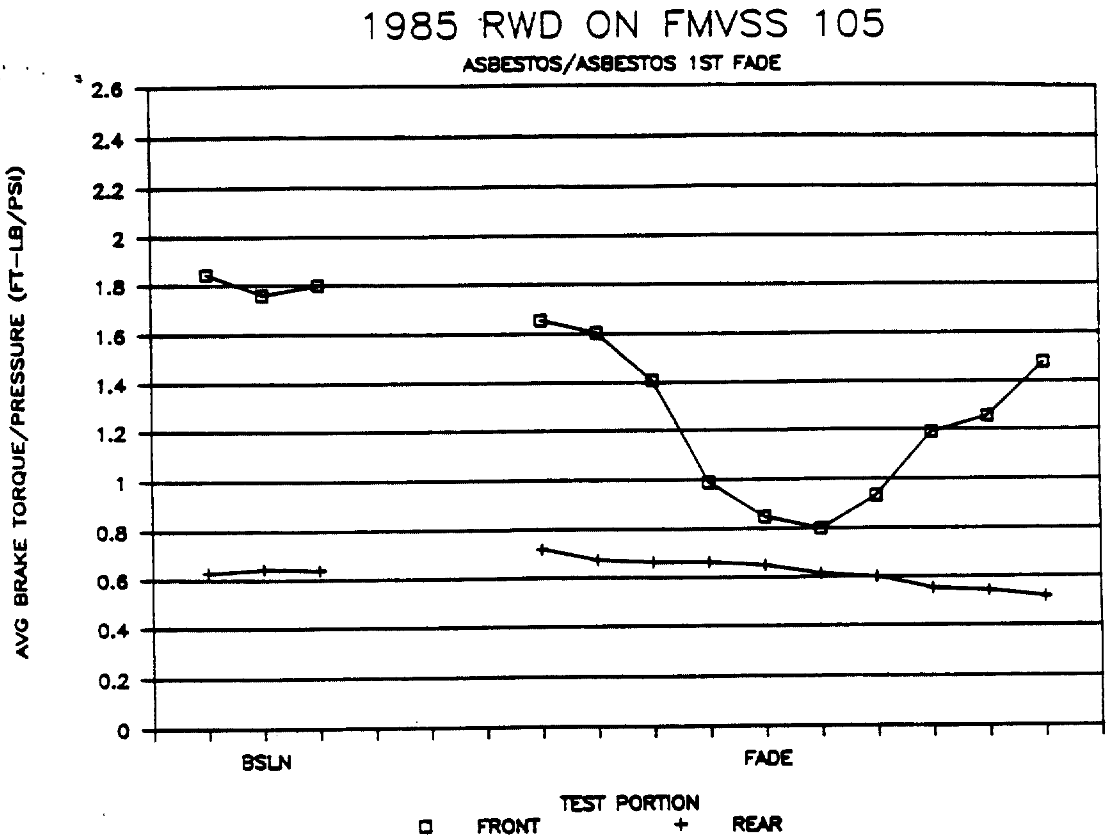

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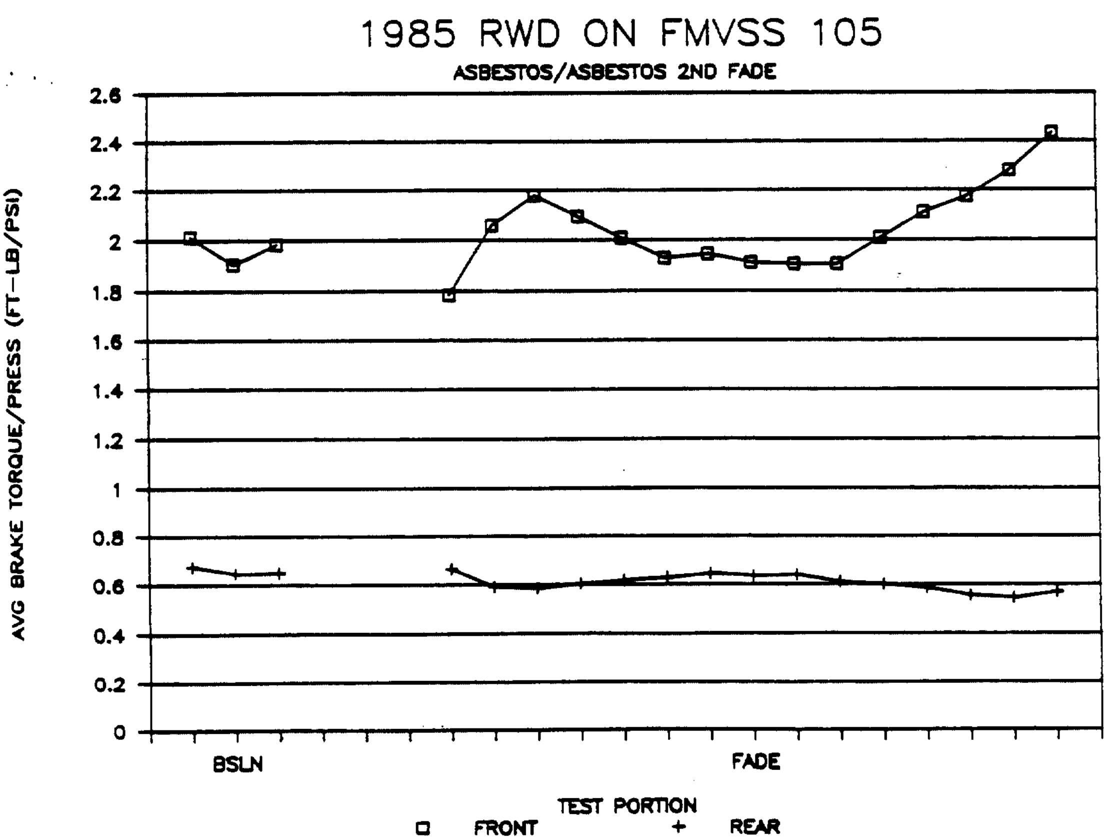

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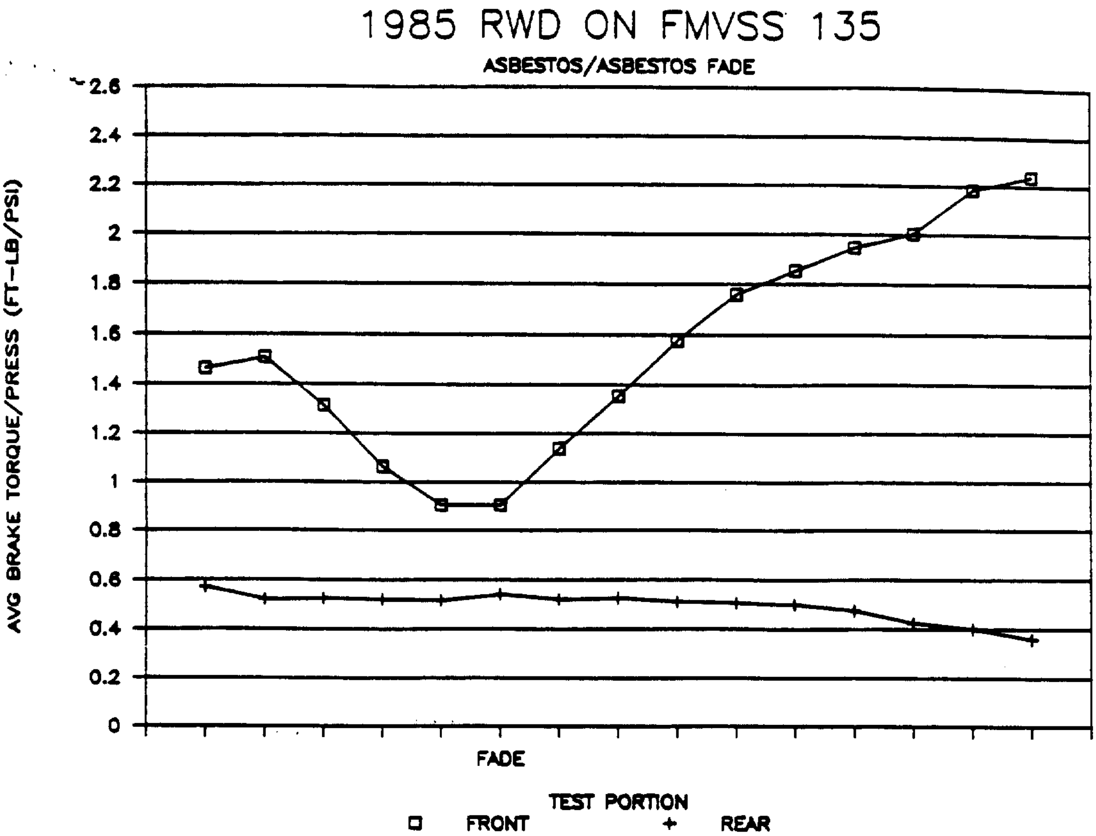

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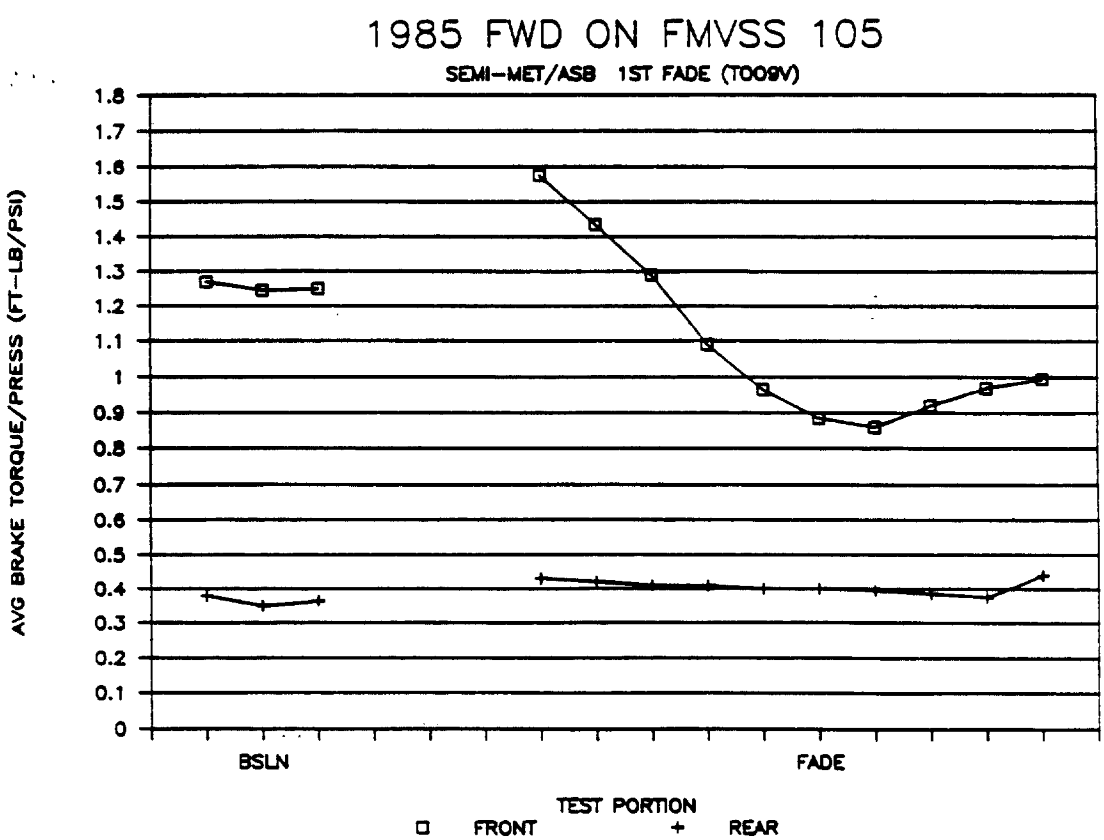

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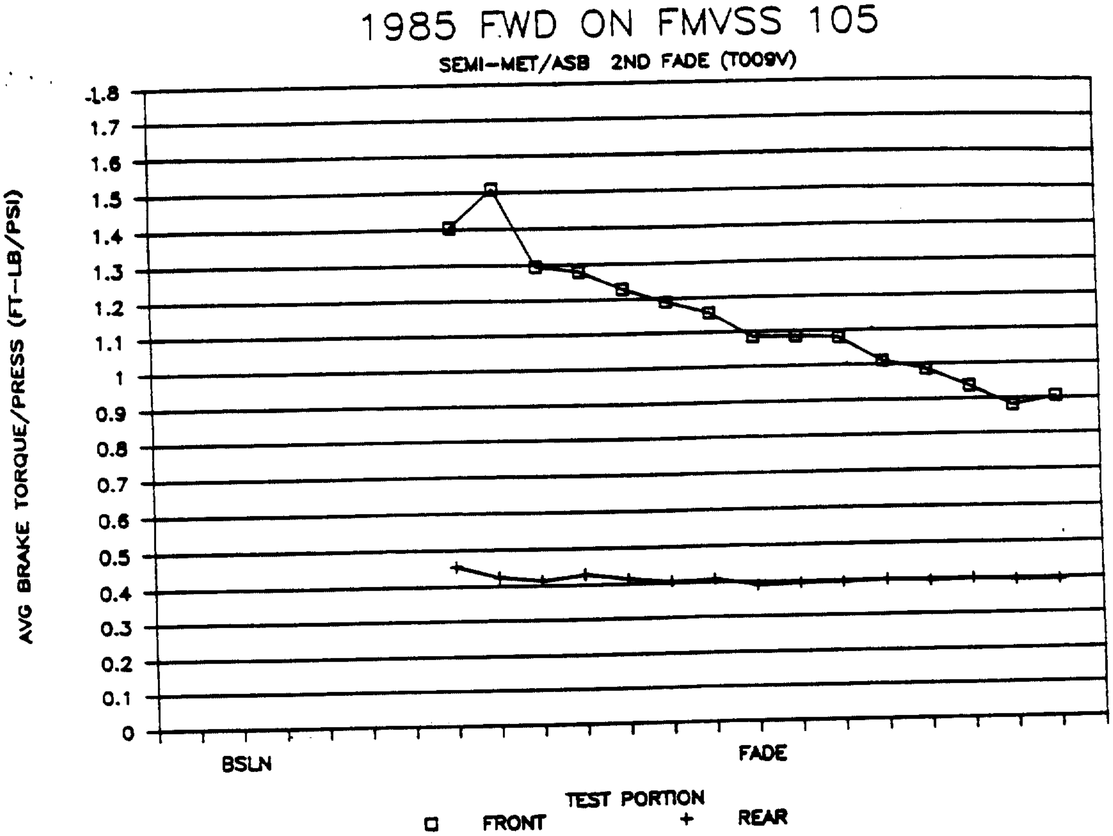

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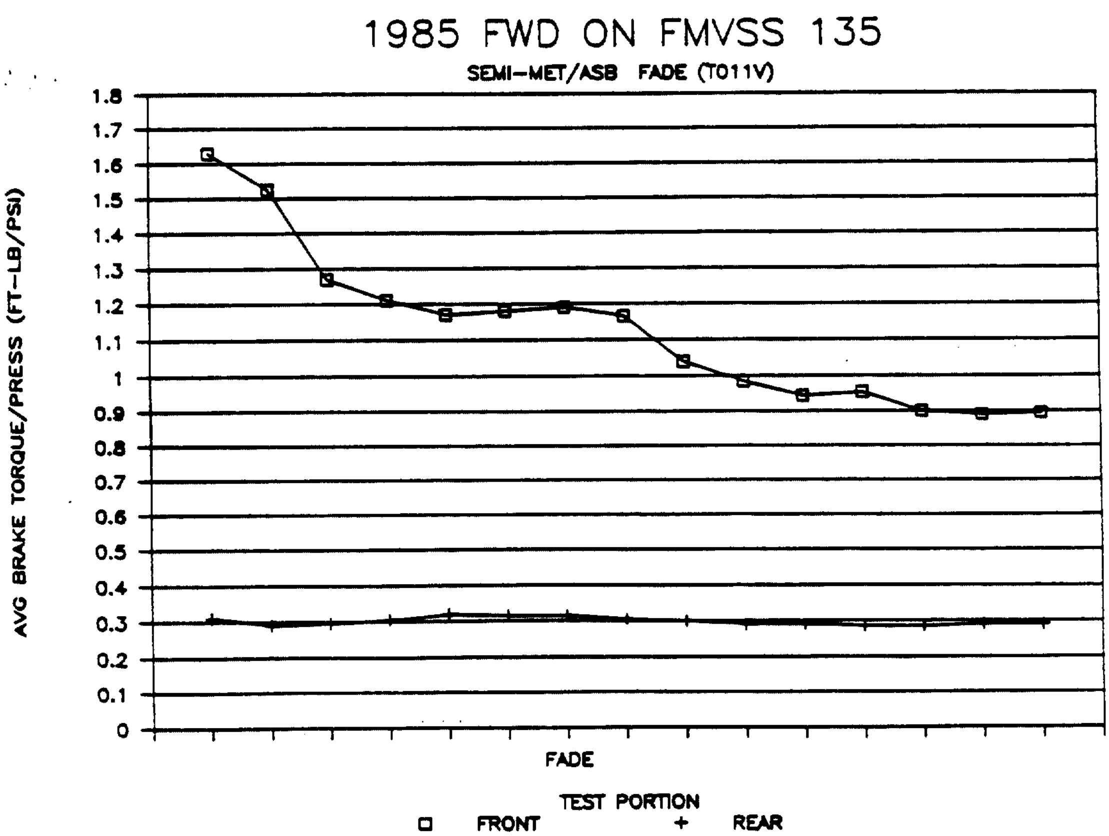

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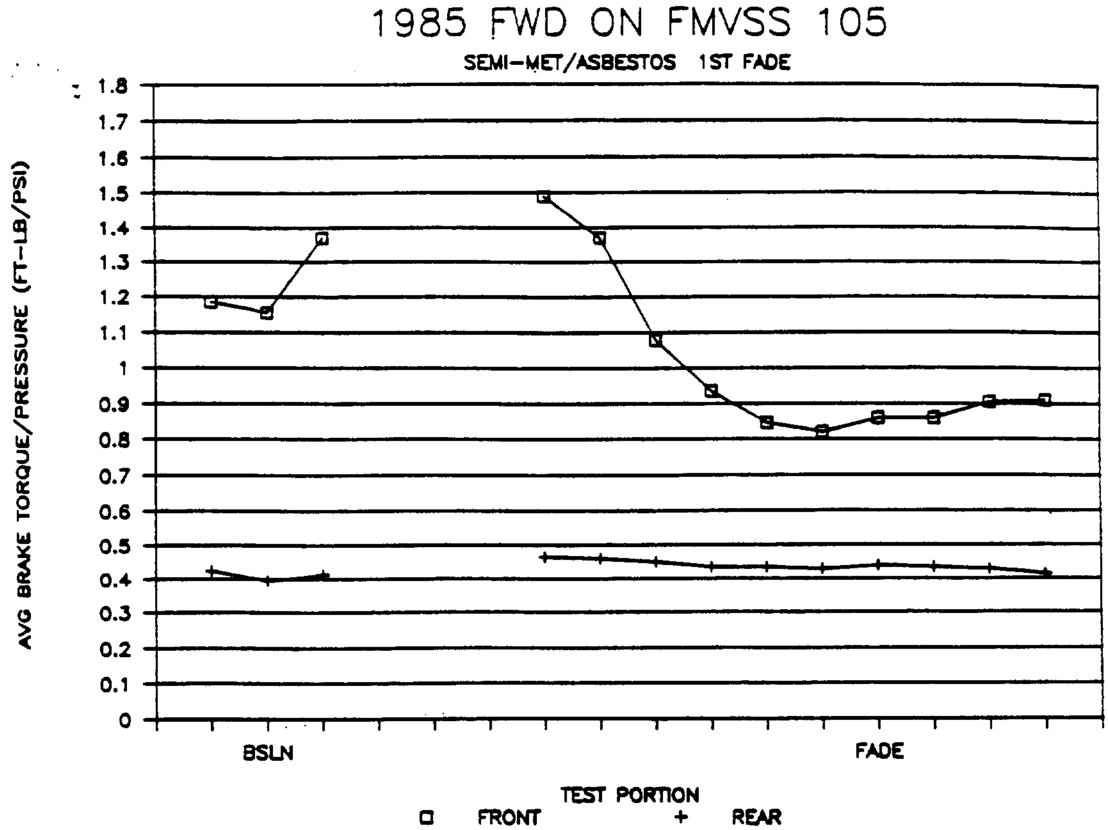

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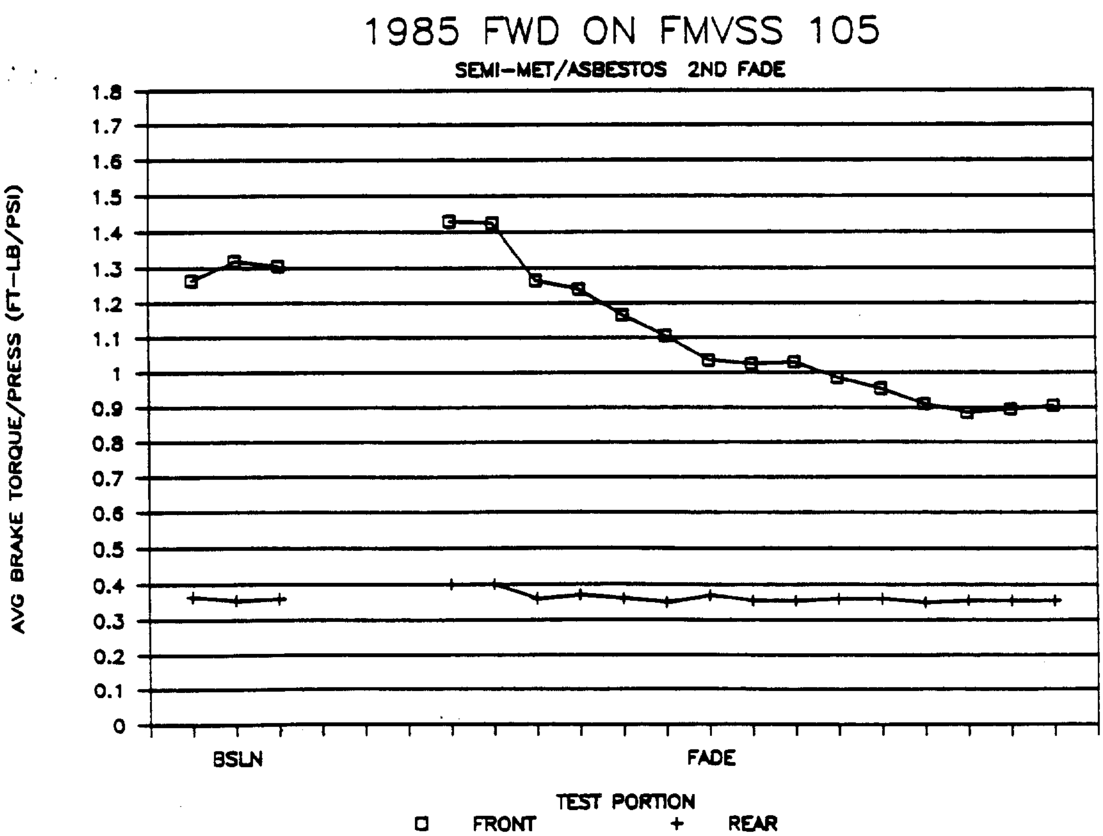

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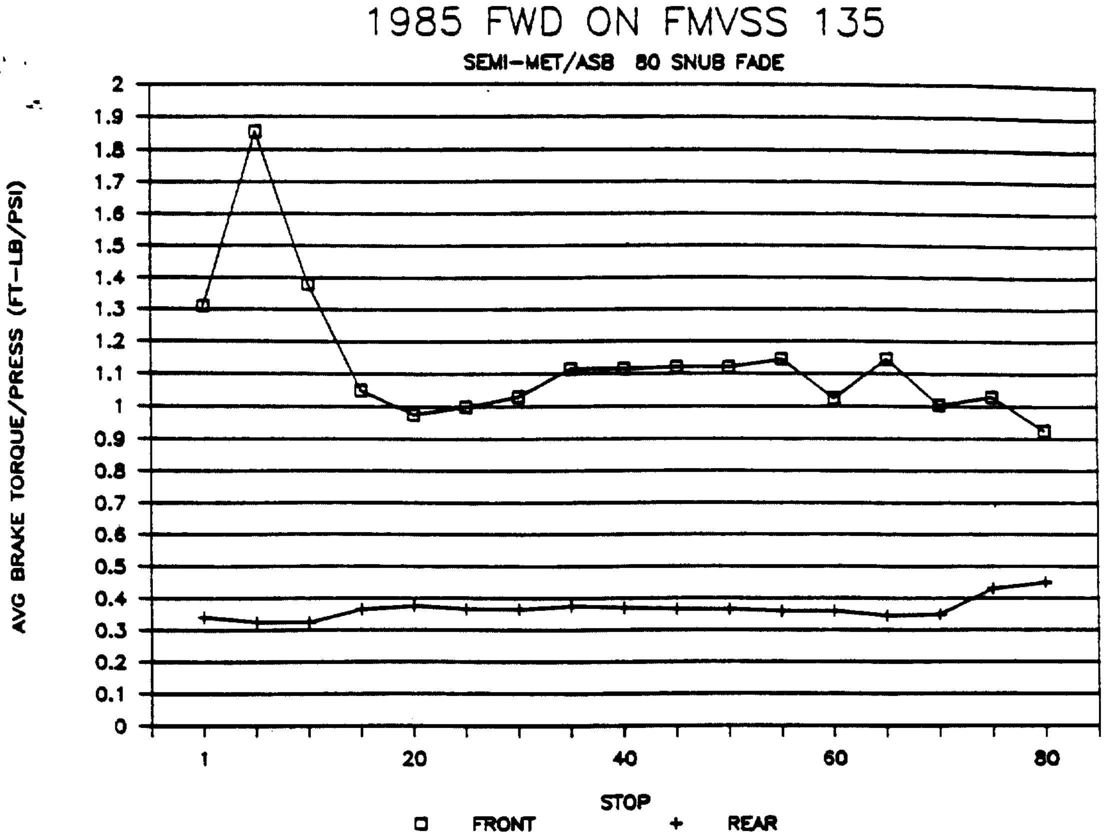
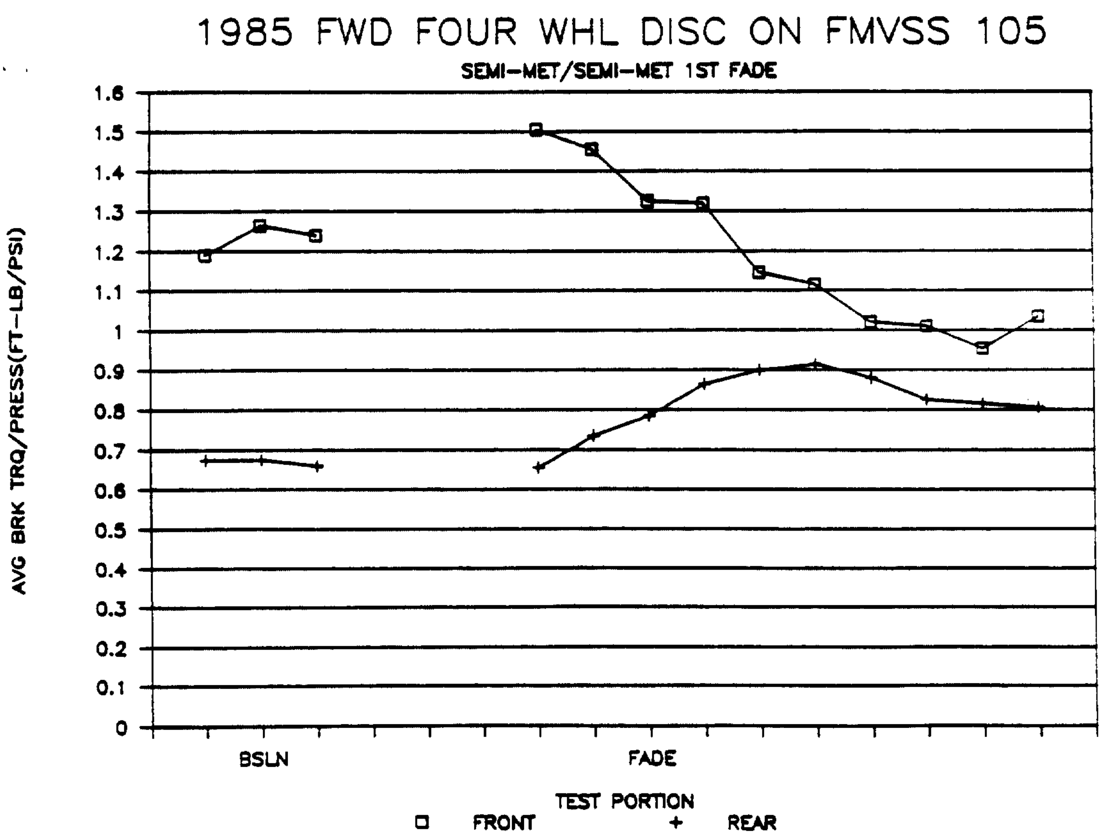


Figure 11



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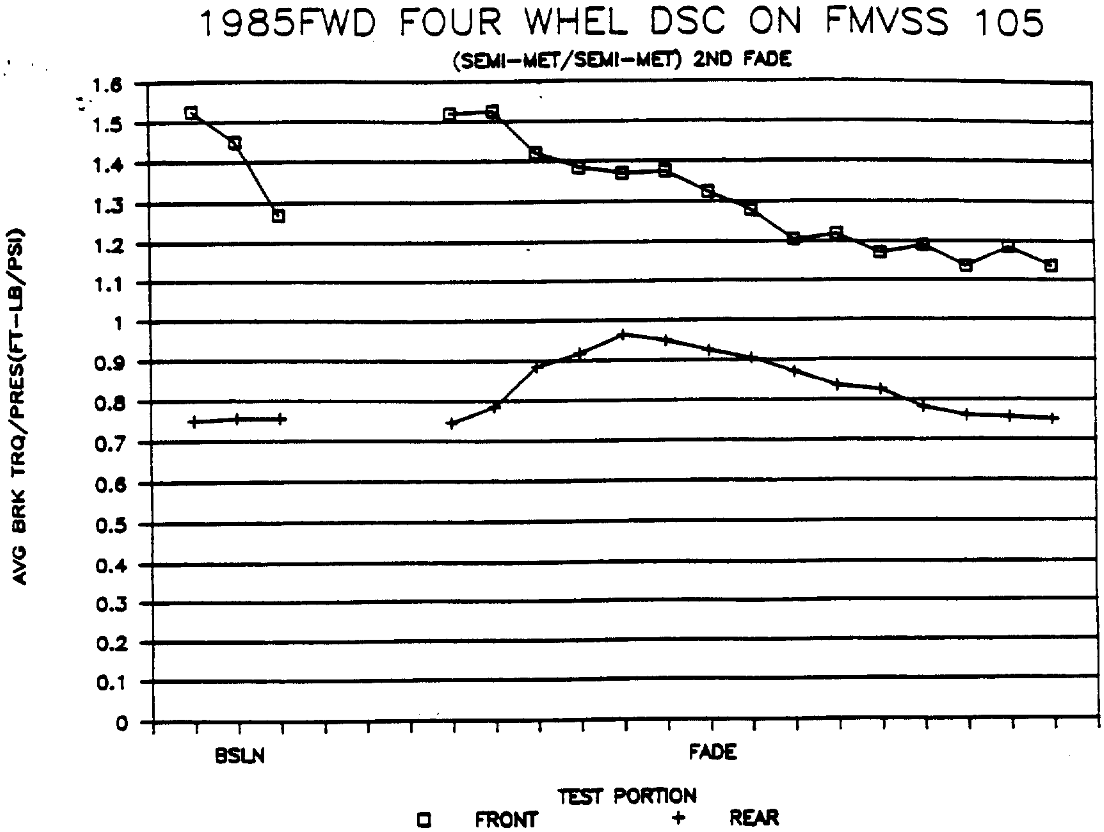

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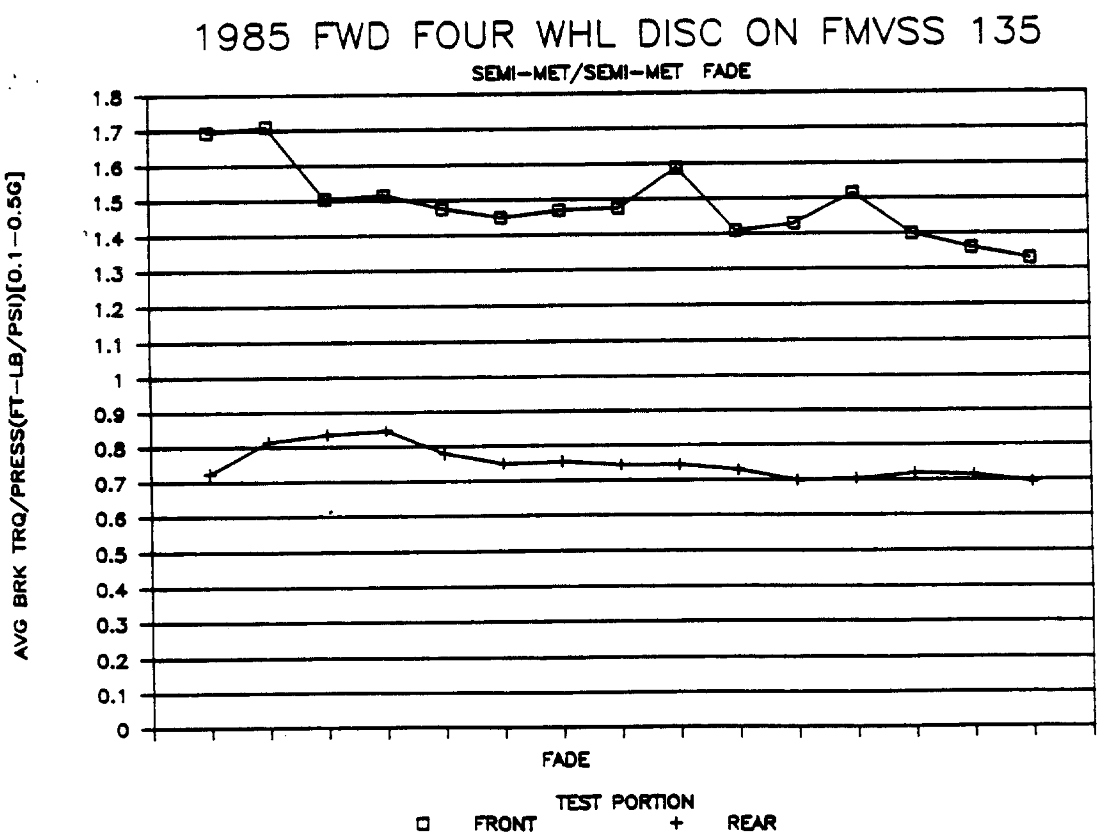

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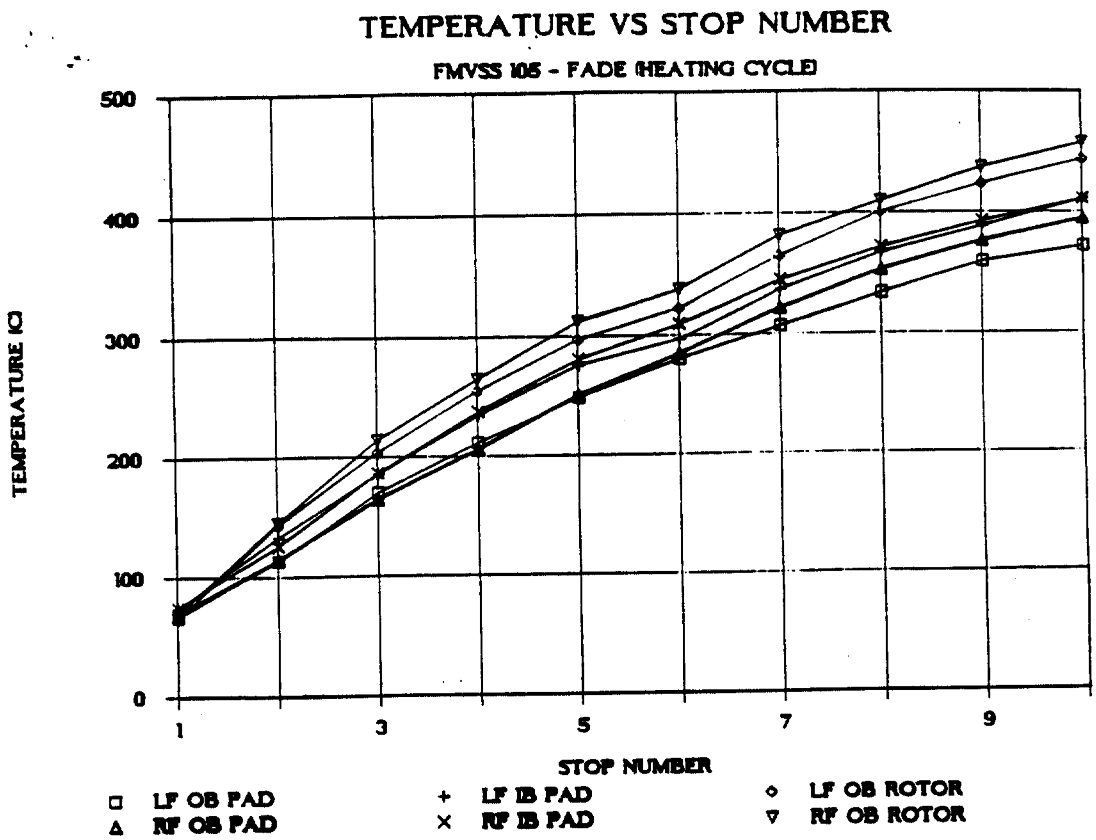

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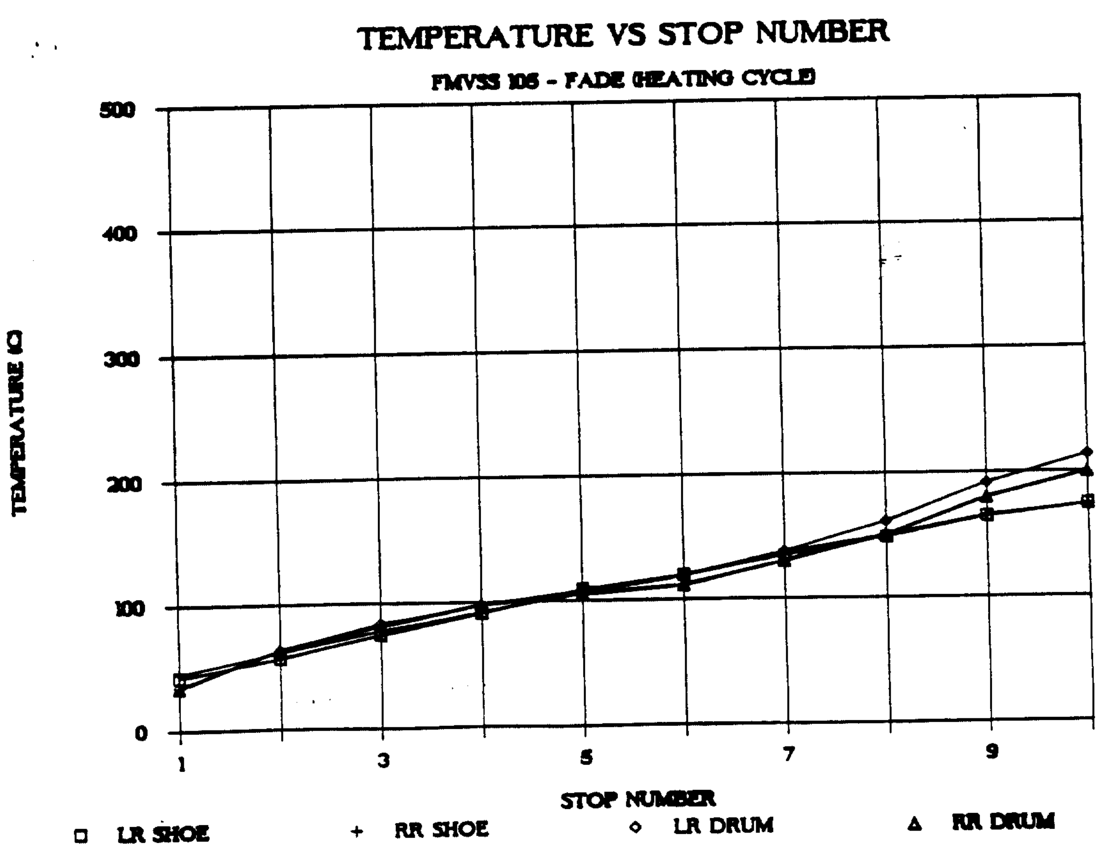

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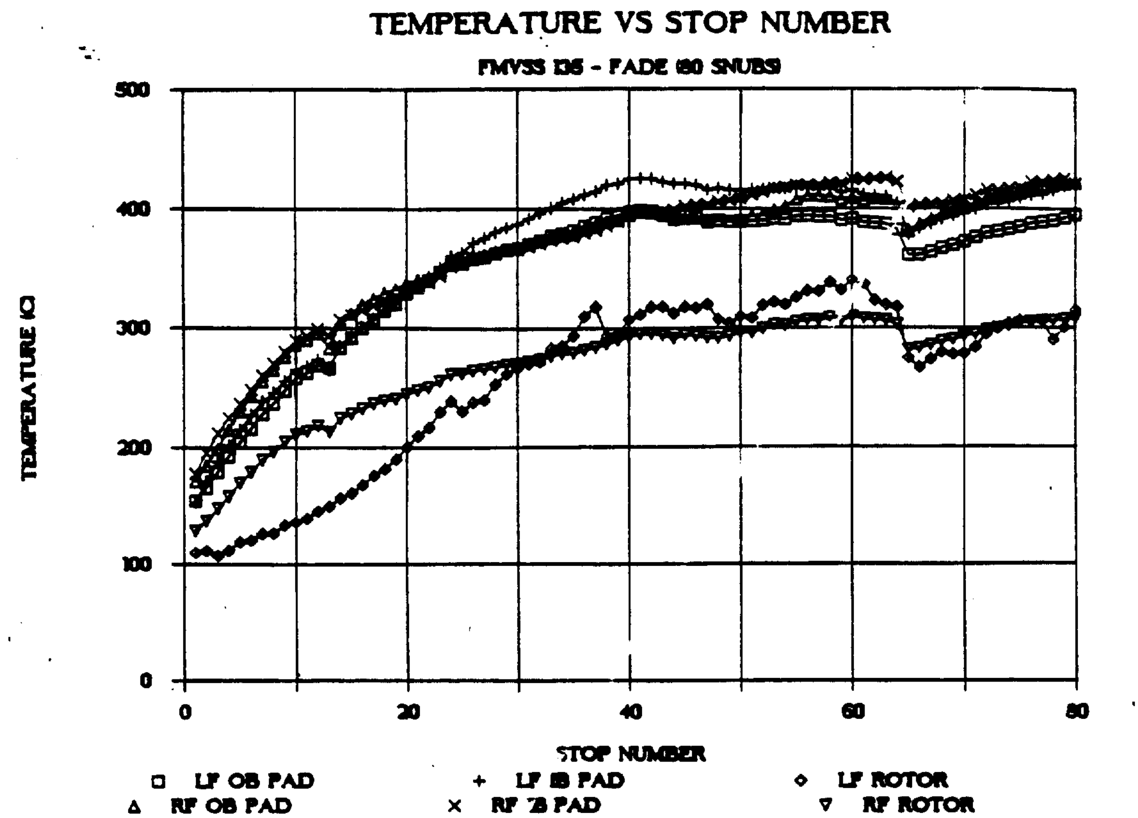

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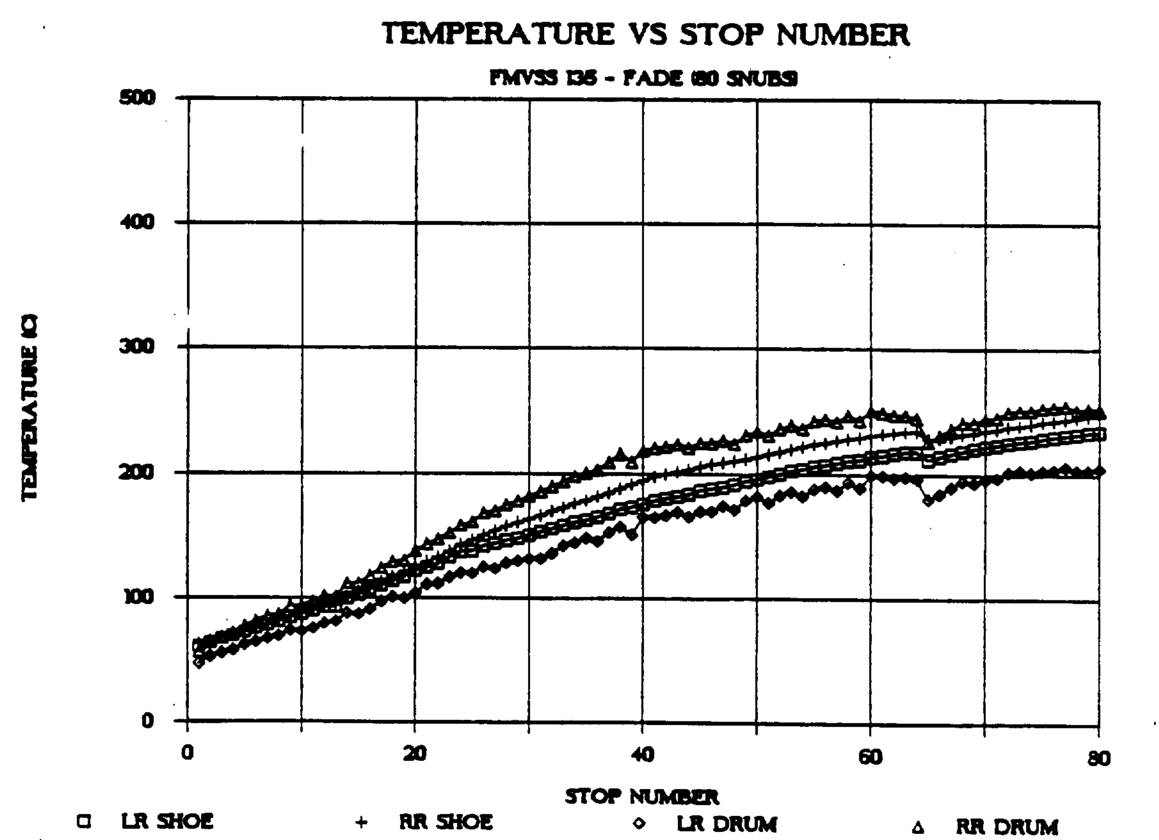

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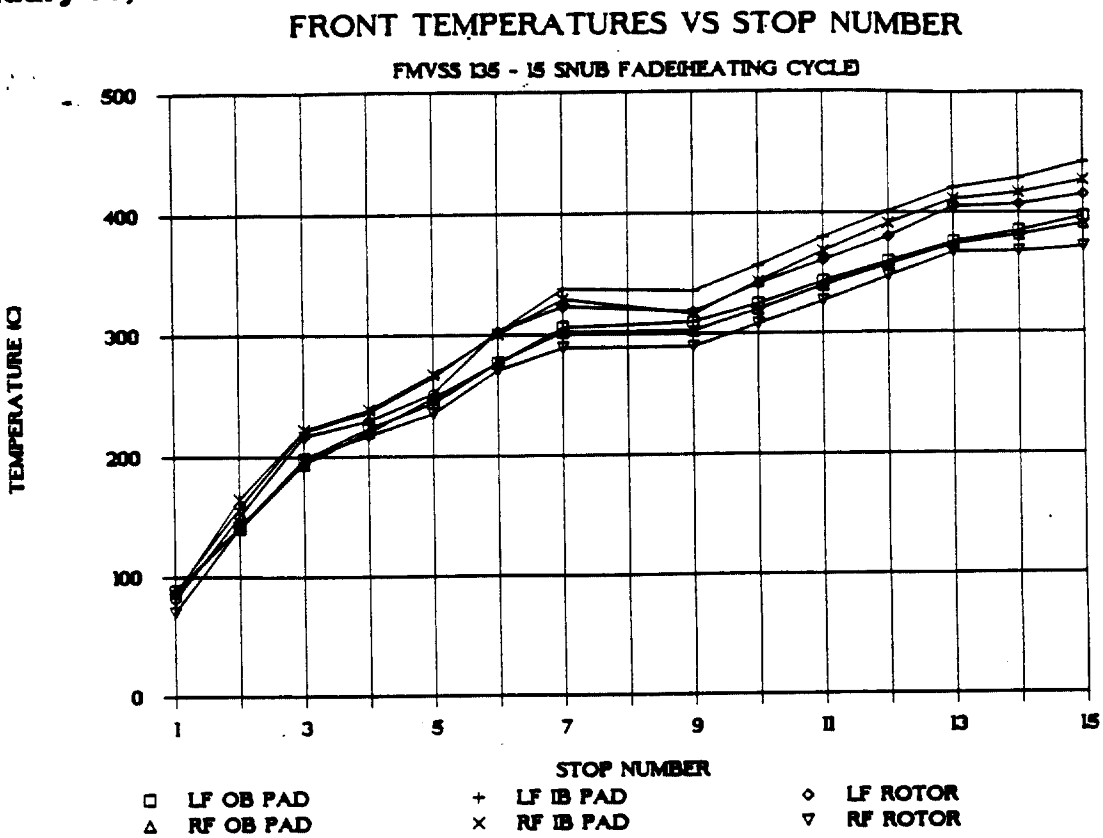

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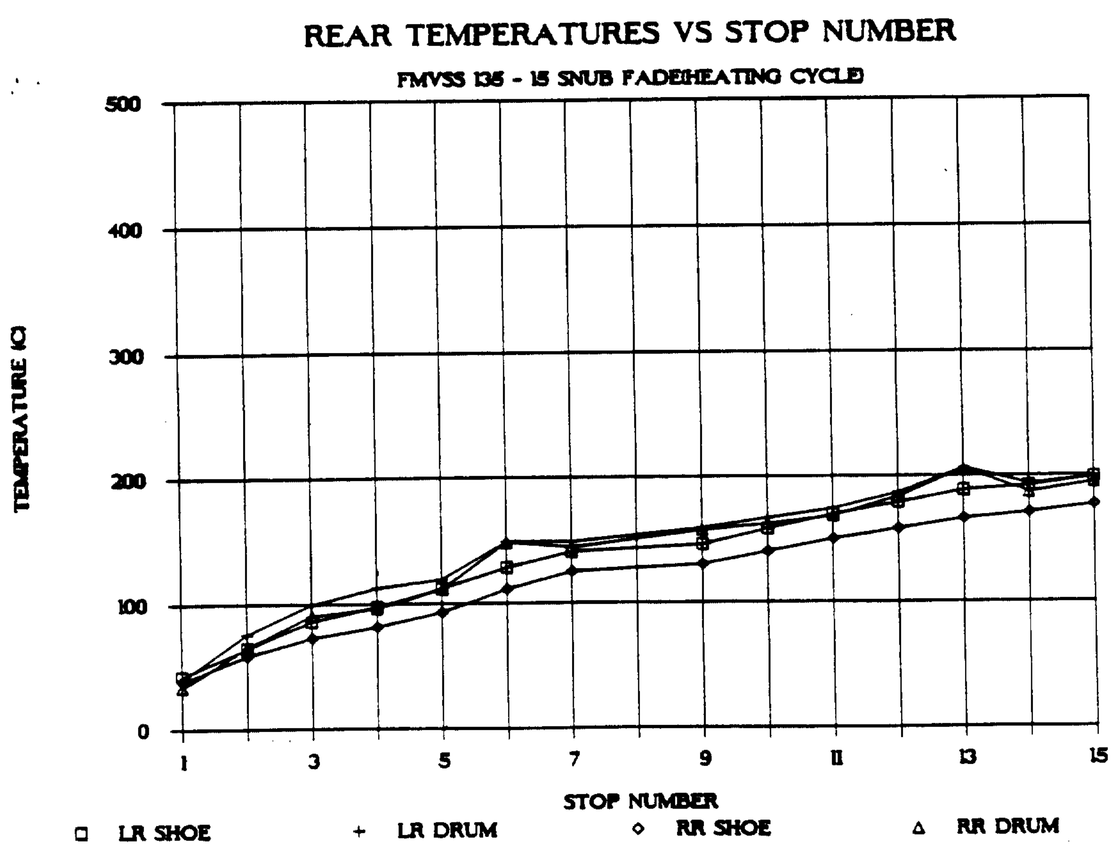

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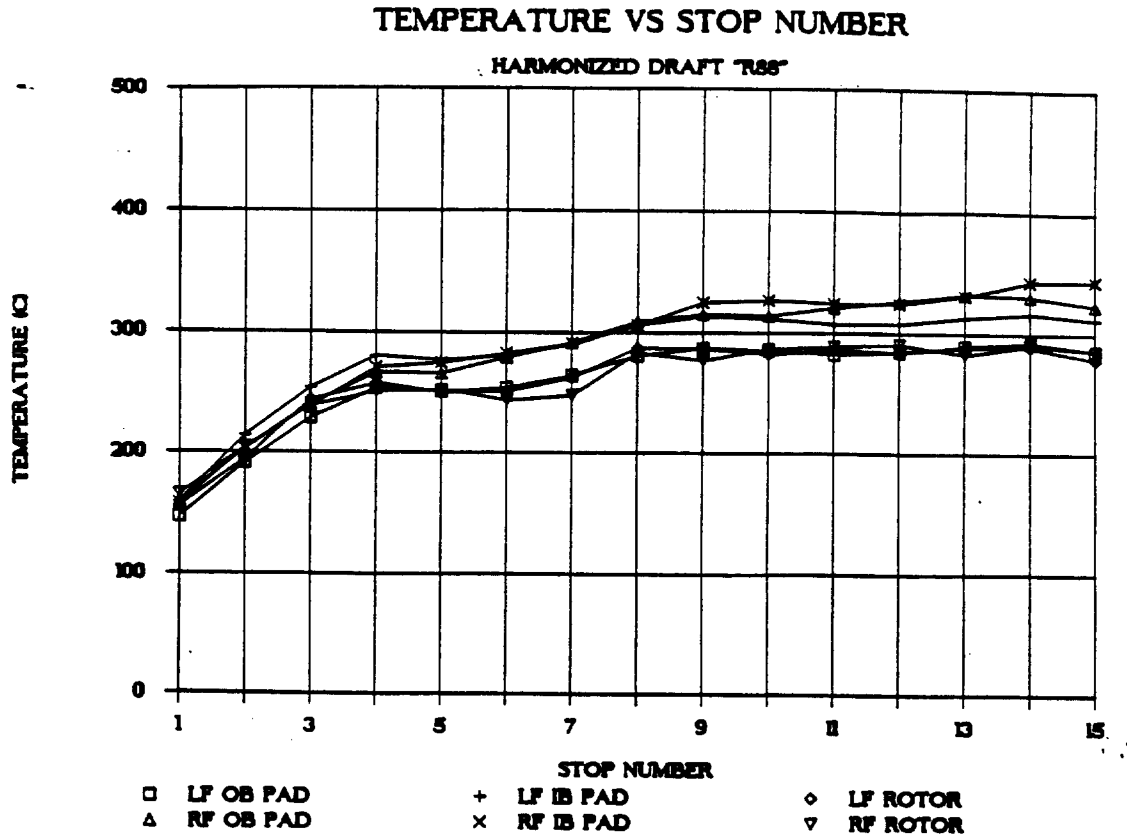

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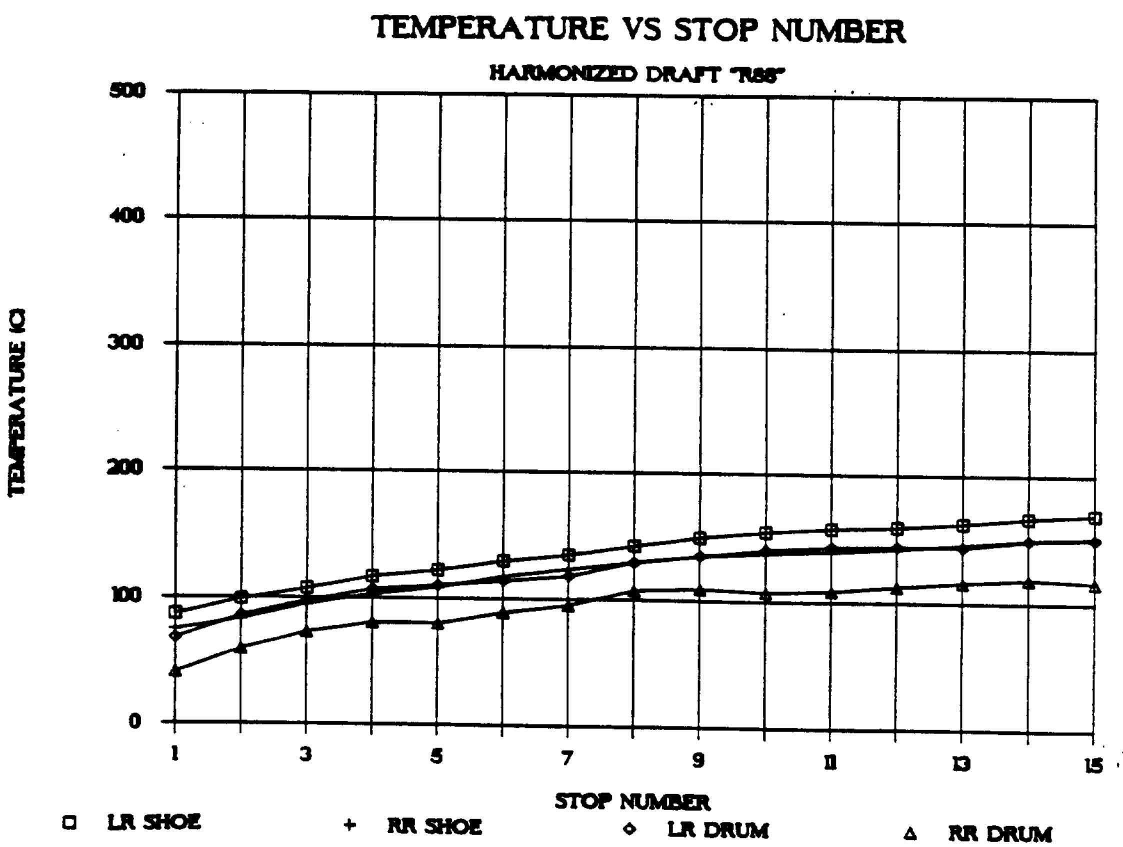

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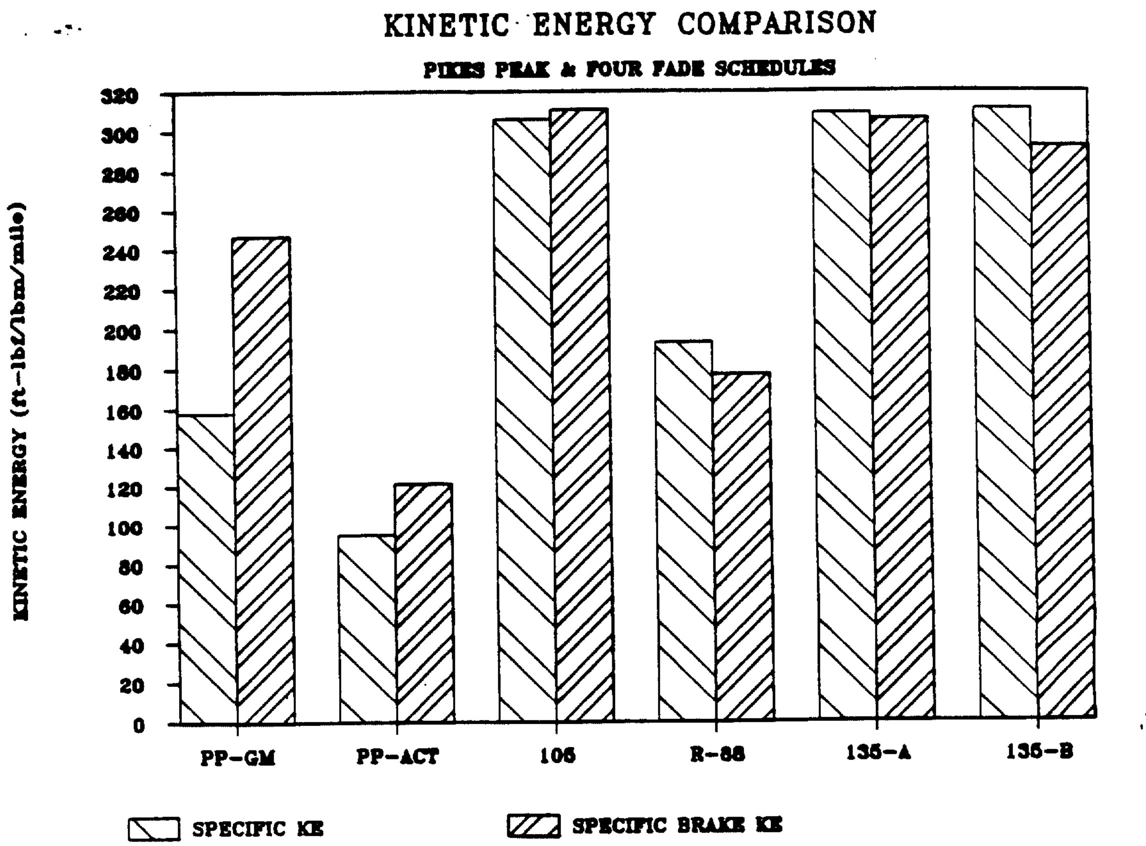

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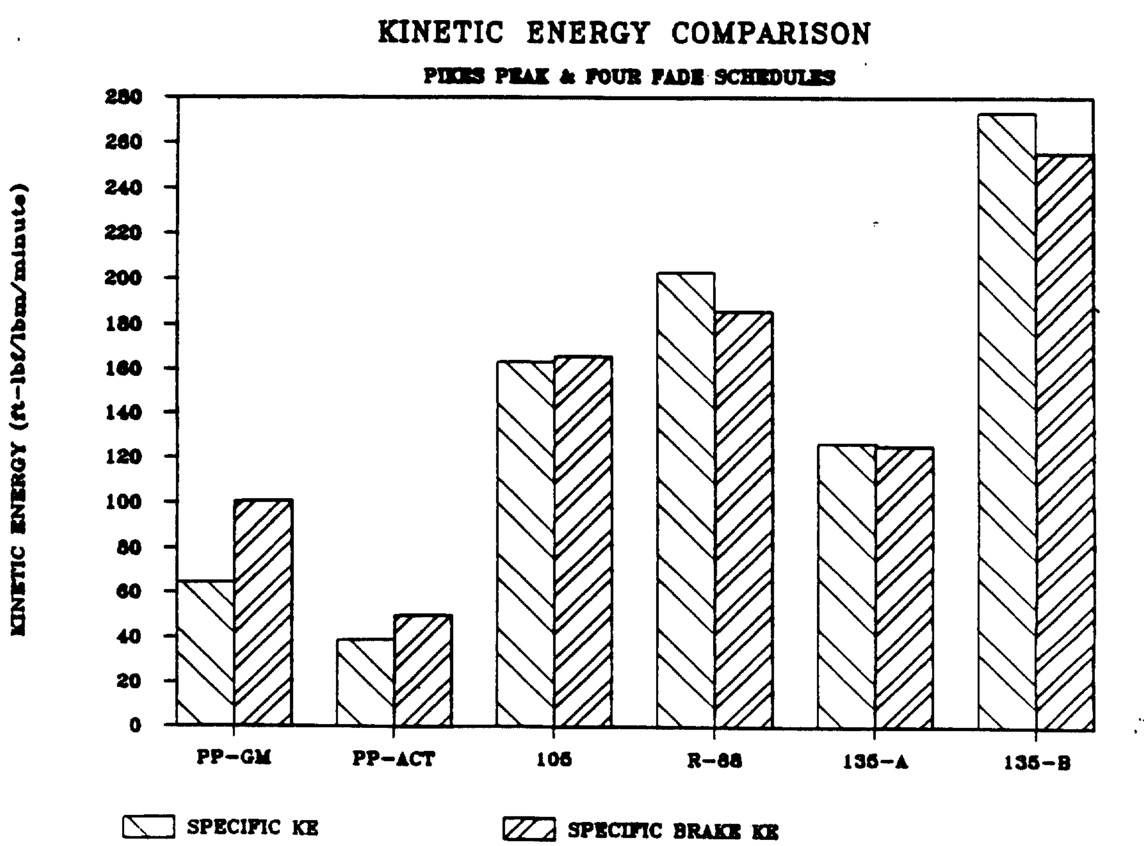

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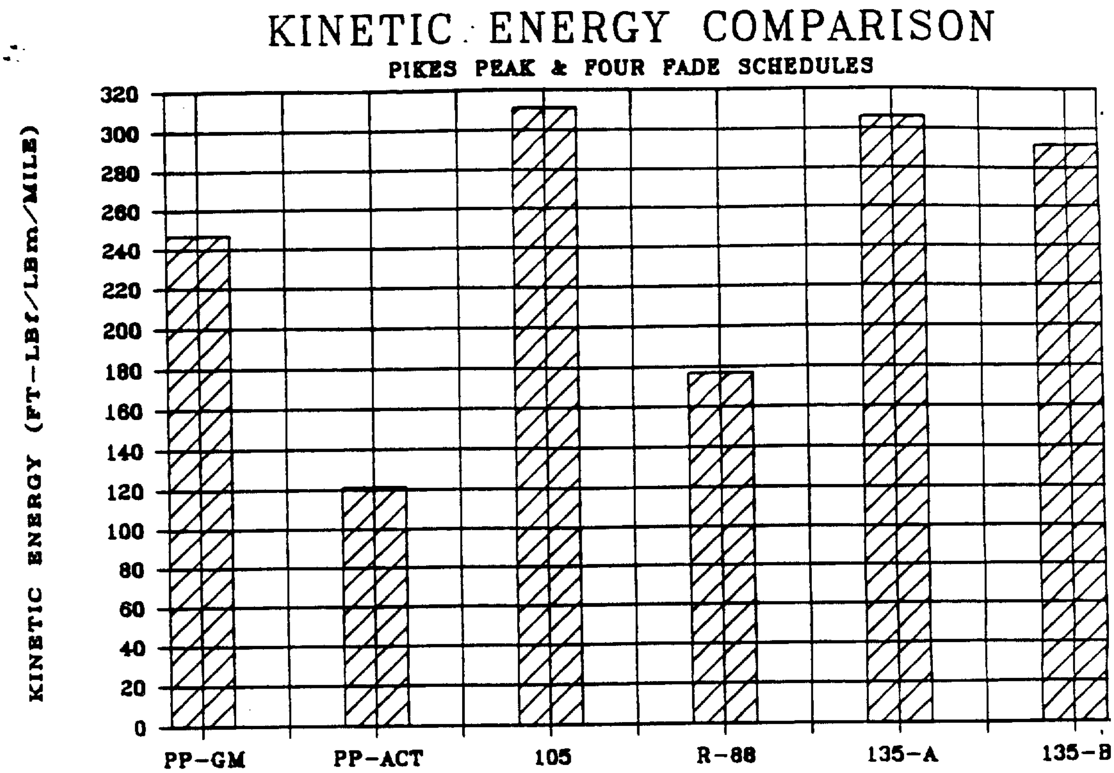

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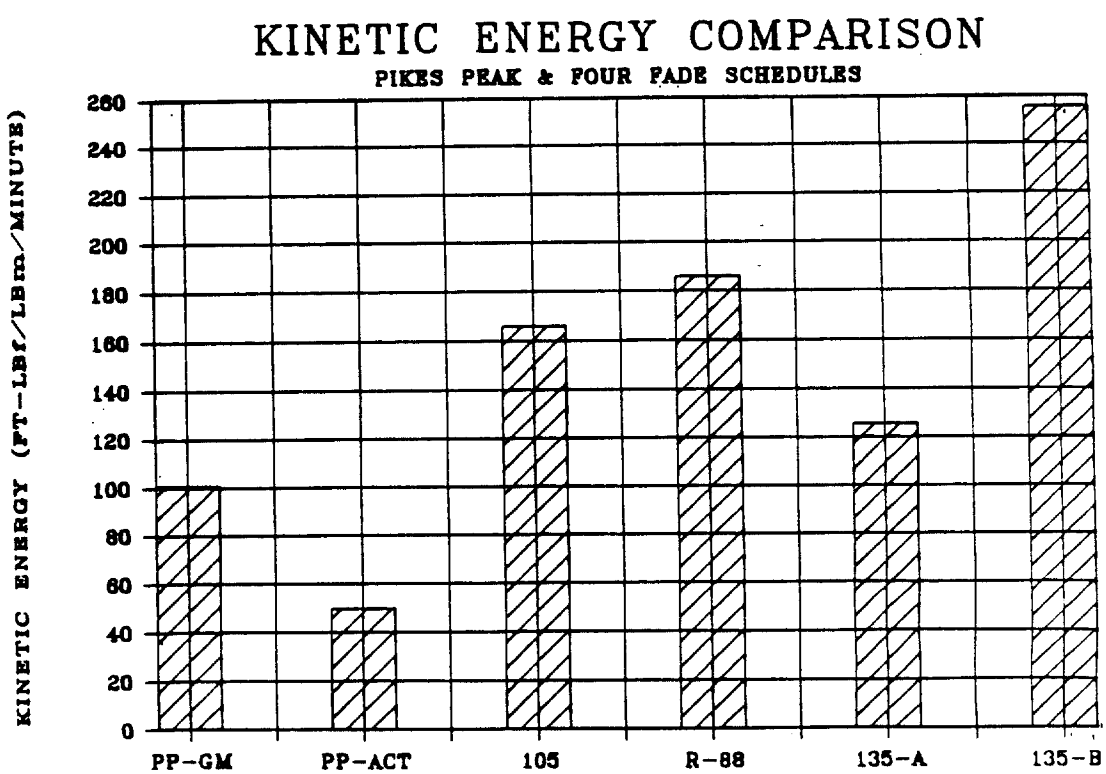


Figure 26

FADE HOT STOP TESTS

OBJECTIVE

The purpose of this Appendix is to discuss the technical facts needed to establish appropriate test conditions and performance requirements for the hot stop portion of the fade and recovery provisions specified in FMVSS 135.

CONCLUSIONS

1. Vehicles currently meeting the ECE Reg. 13 and/or FMVSS 105 are unable to meet the hot stop requirements of FMVSS 135.

2. The hot stop requirements of FMVSS 135 are more stringent than the draft R.88 or the current ECE Reg. 13.

RECOMMENDATION

1. The maximum pedal force limit should be set at 500 N (112 pounds), the same as for other test portions of FMVSS 135 rather than deriving it from the cold effectiveness performance.

2. A single wheel lock up during the hot stop should not constitute a failure.

3. A minimum pedal force limit should be set at a value of 10 pounds.

4. Since hot stop performance is very dependent upon the fade heating cycle to which the brakes are subjected, NHTSA should establish the heating cycle first; then consider the implication of that cycle on achievable hot stop performance before establishing requirements for hot stop.

DISCUSSION

At the outset, GM draws the agency's attention to a discrepency in the Notice regarding hot stop pedal force. Section S5.1.3.1 reads "with a pedal force equal to the average pedal force on the shortest cold effectiveness stop..." In the corresponding test procedure section S7.11.2, the language is: "...at a pedal force not greater than the mean pedal force..." In the Preamble, the agency describes hot stop test condition as ".. allowable pedal force could not exceed the mean pedal force...", For the most part, General Motors comments which follow assume the agency intended "equal to" in specifying the pedal effort.

The proposed FMVSS 135 contains a hot stop effectiveness requirement similar to the one proposed in the ECE draft R.88 as part of the fade and recovery test sequence. This requirement specifies that after completing the heating cycle, the vehicle shall immediately accelerate, and stop from a speed of 62.1 mph (100 km/h) in a distance not greater than the shorter of 91 meters (298 feet) or that achieved in the best cold effectiveness stop divided by 0.60. The test vehicle shall accomplish this with the applied pedal force equal to the mean value of pedal force for the shortest cold effectiveness stop.

Analysis of FMVSS 135 Requirement:

By considering the hot stop test as simply an extension of the heating cycle, but with the driver attempting to achieve the minimum stopping distance, considerable insight can be shed on this element of performance. GM test data indicates that for most cars, a value derived by dividing the best cold effectiveness stopping distance by 0.60 would exceed the 298 feet limit and therefore, the maximum stopping distance allowed on a hot stop test would be set at 298 feet. Assuming a 0.60 second reaction time, this 298 feet of stopping distance corresponds to the equivalent average deceleration of 0.48g as compared to the equivalent minimum average deceleration of 0.70g needed to produce the 214 feet stop required by the cold effectiveness test. This difference in deceleration levels essentially means that the vehicle just meeting the cold effectiveness requirement is allowed to lose a maximum of 31.4% in output at the high temperature levels immediately following the fade heating cycles.

Because this maximum allowable 31.4% reduction in output is based on stopping distance, rather than meeting certain minimum level of deceleration at the beginning of the hot stop test as required by the draft R 88 and ECE R 13 regulations, the brake behavior during the entire stop becomes significant. Consequently, such factors as in-stop fade and gain in effectiveness towards the end of the stop have significant effect on brake performance and must be recognized in monitoring brake output. In summary, the proposed hot stop represents a more rigorous requirement than the draft R.88 or the ECE R 13.

Likewise, the condition of no wheel lock up during stops specified in the proposed FMVSS 135 and the requirement that the vehicle be front biased, precludes any increase in the output of the front brakes for cars that are just capable of meeting the cold effectiveness requirement. To understand this finding, one must recognize the fact that the hot stop test is performed at the GVW loading condition, the same as is specified for the cold effectiveness test which provides the basis for computing the maximum allowable stopping distance during the hot stop test. Consequently, if the driver is truly making the shortest cold effective ness stop, the vehicle deceleration is limited by the tire to road adhesion on the front axle. Now, with faded brakes, if the driver applies the same pedal force used during the best cold stop for the hot stop test, and recognizing the fact that the front brakes have experienced an increase in brake output as a result of fade cycles, then by definition the front wheels will lock up. This constitutes a failure to meet the requirements of FMVSS 135. However, if the NHTSA intention is to specify the pedal force "not greater than" the best cold effectiveness stop as indicated in the Preamble discussion, then the pedal force can be reduced and the above comments regarding an increase in brake output and the possibility of a failure due to wheel lock up does not apply.

Thus, based on the above arguments, General Motors observes that a vehicle just meeting the cold effectiveness requirement can fail to meet the hot stop requirements of the proposed FMVSS 135 in one of the two ways; either experience more than 31.4% loss in system effectiveness due to heating cycles and fail the stopping distance requirement or experience front wheel lock up due to an increase in front brake effectiveness. On the other hand, a vehicle that has greater compliance margin in a cold effectiveness stop but has a larger system effectiveness loss due to heating cycles exposure is restricted from using a higher pedal force than the value achieved during the cold effectiveness stop. Therefore, to properly recognize the relevance of these observations, General Motors concludes that specifying the pedal force limit based on results of the cold effectiveness test is inappropriate. Instead, General Motors recommends that the maximum pedal force should be set at 500 N (112 pounds).

FMVSS 135 vs FMVSS 105:

FMVSS 105 does not specify a hot stop requirement. However, FMVSS 105 requirements may be compared to the hot stop requirement of the proposed FMVSS 135 if one considers the hot stop as simply an additional fade heat cycle stop. The following analysis is offered.

The maximum burnished cold effectiveness stopping distance proposed in FMVSS 135 is 214 feet from 100 km/h. If a test vehicle just meets this requirement, then its hot stop requirement under FMVSS 135 would be 298 feet (the shorter of the two proposed performance levels; the specified 298 feet, or the calculated value of 356.7 feet which is derived by dividing 214 feet by a factor of 0.60). As shown earlier in this Appendix, the 298 feet stopping distance translates to an equivalent minimum average deceleration of 0.48g or 15.5 ft/sec^2. Thus, the minimum deceleration level required under FMVSS 135 during the hot stop is more than three times that specified during the fade heating cycles under FMVSS 105 which is 5 ft/sec^2.

Further, the maximum allowable loss in brake system output under FMVSS 105 is more than twice that allowed under the proposed FMVSS 135. The following analysis is offered to substantiate this analysis.

Under FMVSS 105, the burnished cold effectiveness stopping distance requirement is 204 feet from 60 mph which, assuming reaction time of 0.60 second, translates into an average vehicle deceleration requirement of 0.68g or 21.9 ft/sec^2. The minimum vehicle deceleration rate during the fade heating cycles under FMVSS 105 is 5 ft/sec^2. Comparing the two deceleration values, a brake system loss in effectiveness of up to 77.9% is allowed under FMVSS 105. The maximum pedal effort of 150 pounds under FMVSS 105 would further increase this computed allowable brake system loss. As shown earlier in this Appendix, the maximum allowable brake system loss under FMVSS 135 is 31.4%.

FMVSS 135 vs. R.88:

Draft proposal R.88 contains a hot stop requirement calling for different performance limits. In particular, R.88 limits the permissible change in brake output due to the heating by specifying that hot stop distance must be no less than the burnished brake stopping distance requirement divided by 0.80 and also, no more than the actual performance of the vehicle during the burnished brake test divided by 0.60, without correction for brake system reaction time. The burnished brake performance requirement in R.88 prescribes a stopping distance of 252.6 feet or less from 100 km/h. This translates to a hot stop maximum stopping distance of 308 feet and assuming a 0.60 second reaction time, results in an equivalent minimum average deceleration of 0.46g or 14.8 ft/sec2. The actual performance divided by 0.60 limit on hot stop distances is obviously influenced by the actual test vehicle. This requirement is only more restrictive than the 308 feet limit when the actual vehicle produces a burnished brake stopping distance of 198 feet or less from 100 km/h which is derived by applying the 0.60 factor to 308 feet without correcting for reaction time. Thus, for all but a very few vehicles, the hot stop requirement of 308 feet from 100 km/h is the limiting case, and a vehicle would fail the R.88 hot stop if it were unable to stop from 100 km/h within this distance while maintaining a pedal force <u>not greater than</u> the mean pedal force actually measured in the best burnished brake stop.

To determine the degree to which the R.88 requirement limits changes in brake system output, assume the test vehicle achieves a best cold burnished brake stopping distance of 230 feet from 100 km/hr. Assuming the same brake system reaction time of 0.60 seconds, this is equivalent to an average deceleration of 0.64g (19.8 feet/sec^2), and compared to the 0.46g deceleration required during the hot stop brake performance, this shows that the brake system output change is limited to a 28% reduction. However, R.88 does not specify any limit to which the front brake could increase in output because the pedal force can be reduced to avoid wheel lock up. In fact, the increase in front brake output would be allowed to compensate for decreased rear brake output as most vehicles are capable of achieving more than 0.46g with front brakes alone when the vehicle is loaded to the GVW condition.

FMVSS 135 vs. ECE R13:

ECE R13 contains similar performance criteria except that the pedal force is limited to a maximum of 500 N (112 pounds). A cold effectiveness requirement of 166 feet allowed from 80 km/h (50 mph) in ECE R13 is approximately equivalent to the 256 feet from 100 km/h. This then would limit the hot stop performance to a maximum of 312 feet using the 0.80 correction factor and the burnished brake performance requirement. A vehicle requiring more than 200 feet of stopping distance from 100 km/h (approximately 130 feet from 50 mph) would not be limited by the 0.60 correction to actual test vehicle performance. Thus a vehicle would fail the hot stop requirement of ECE R13 if it were unable to stop from 100 km/hr in 312 feet with a pedal force limited only to a maximum of 112 pounds. This again corresponds to the FMVSS 135 requirement of 298 feet at a pedal force equal to the pedal force measured in the best cold effectiveness stop.

Analysis of Pedal Force Condition:

Since pedal force limits are rarely achieved in cold burnished brake performance tests, the degree to which the brake system may experience changes in output as a result of fade heat cycle exposure is limited to the sum of two components. The first is the degree to which pedal force may be increased above the level used in the burnished brake performance test. The second is the degree to which the brake system output or effectiveness is allowed to decrease as a result of the lowered deceleration rate that must be delivered during the hot stop.

For example, assume a vehicle on ECE R.88 test achieves a burnished brake stopping distance of 230 feet from 100 km/h with an average pedal force of 80 pounds. Again, this is equivalent to a minimum average deceleration of 0.64g. If the pedal force/deceleration relationship is linear (no booster run-out is encountered) then an additional 37.8% in brake system output could be gained by increasing pedal efforts to 500 N (112 pounds). When this is added to the 28% reduction in vehicle deceleration required in the hot stop, the total brake system loss in effectiveness could be as much as 65.8% and still meet the requirements of ECE R.88. The corresponding maximum allowable loss on FMVSS 135 test would be 62.8%.

Based on all the observations above, it should be clear that both R.88 and the proposed FMVSS 135 represent substantial increases in fade requirements over either FMVSS 105 or ECE R13. The justification for limiting the maximum pedal forces during the hot stop to the mean value of the forces used in the burnished brake performance test are not obvious. Any driver allowed to apply 112 pounds of pedal force in other portions of the test would retain that capability during the fade hot stop portions of FMVSS 135.

General Motors Test Program:

Given the above explanation of the hot stop requirements in terms of allowable limits of brake system effectiveness change, GM offers the results of its substantial test program evaluating the performance capability of current production vehicles that meet the requirements of FMVSS 105. As noted earlier, for purposes of evaluating brake performance during fade cycles as if they were stopping distance tests, the brake performance over the entire stop must be recognized. To meet this need, front and rear brake output was averaged over the entire brake application without any correction for holdoff pressures. This approach was adopted simply to expedite the data reduction, and since relative performance comparisons can be made, this degree of data reduction without correcting for hold off pressure was judged to be sufficient. Brake system output during both FMVSS 105 and

FMVSS 135 test procedures have been studied in the GM test program to identify the performance capability of current technology designs and materials.

RWD Vehicle, FMVSS 105 Test:

The front and rear brake output during the baseline, first fade, and recovery portions of FMVSS 105 for a RWD vehicle equipped with semi-met front brake materials and asbestos rear brake materials are shown in figure 1. During the fade heating cycle, we see an initial increase in front brake output lasting perhaps 3 stops, then a decrease of front brake output in the next four stops, and a consistent front brake output in the last three stops of the 10 stop first fade heat cycle. The rear brake output demonstrates a smaller monotonic decrease during the 10 stop sequence. After reburnish, the second fade and recovery sequence is shown in figure 2. We see a similar trend at both ends of the car, but the degree of change is smaller, and requires more stops to achieve. This observation suggests that the prior exposure to the first fade heating cycle and subsequent reburnish has conditioned the linings to deliver better performance during the second fade sequence. This is a highly relevant finding since the fade sequence in FMVSS 135 provides no similar provision for preconditioning of the lining to fade cycle temperatures.

FWD Vehicle, FMVSS 105 Test:

Similar trends, but larger percentage changes in front brake output, are shown in the results for the FWD vehicle shown in figures 3 and 4. Whereas the front brake output reduction in the RWD FMVSS 105 test was perhaps 28%, the FWD design experienced front brake output changes of the order of 40% or more. This result is a consequence of the fact that a larger fraction of the total vehicle braking is accomplished with the front brakes in the FWD design than is accomplished with the front brakes in the RWD design. This finding points out that requiring larger degrees of front bias will only exacerbate the burden placed on the front braking systems of vehicles during fade and recovery tests.

Modified FWD Vehicle, FMVSS 105 Test:

The FWD vehicle equipped with a slightly lower output rear brake lining was run through the FMVSS 105 fade and recovery procedure and the front and rear brake output changes that resulted are shown in figures 5 and 6. The results shown for this vehicle are quite consistent with those shown in figures 3 and 4.

FWD Vehicle, 4 Wheel Disc, FMVSS 105 Test:

The FWD vehicle equipped with a four wheel disc brake system and semi-metallic friction materials on both axles was also studied and the FMVSS 105 fade and recovery behavior is shown in figures 7 and 8. The rear disc brake behavior in this test is quite interesting in that the changes in performance show a similar trend to those seen in the fronts, but at a much lower rate. This is attributed due to the lower energy input to the rear brakes.

RWD Vehicle, Asbestos Front, FMVSS 105 test:

The RWD vehicle was also studied when equipped with asbestos friction materials on the front disc brakes and the behavior in FMVSS 105 fade and recovery tests is somewhat different. The asbestos friction materials on the front disc brakes experience a large decrease in output during the first five stops of fade heating with some substantial recovery during the last five stops of the same heating cycle as shown in figures 9. A similar trend, but with much smaller changes is noted in the second fade and recovery test of FMVSS 105 for this friction material as shown in figure 10. Again, the prior exposure to high temperatures during the first fade and recovery seems to offer improved resistance to subsequent exposures.

FWD Vehicle, 15 Snub FMVSS 135 Test:

The actual hot stop performance of semi-metallic/asbestos and semi-metallic/semi-metallic versions of the FWD vehicle in FMVSS 135 fade and recovery tests, is shown in figures 11 and 12. Here the characteristic loss of front brake output with semi-mets is seen during the fade heating cycle (15 snub), but the immediate application of the hot stop test neither increases or decreases front or rear brake output beyond the fully faded condition, as shown in both tests.

FWD Vehicle, 80 Snub FMVSS 135 Test:

The 80 snub fade option of FMVSS 135 was studied on a semi-metallic/asbestos equipped FWD vehicle with digital data taken for every fifth stop and the resulting change in front and rear brake output is shown in figure 13. When tested to this particular heating cycle, the front and rear brake outputs of this specific vehicle have essentially stabilized after 20 snubs, and subsequent applications of the brakes appear irrelevant.

RWD Vehicle, 15 Snub FMVSS 135 Test:

Finally, the 15 snub fade option of FMVSS 135 was studied on a asbestos friction material equipped RWD vehicle and fade and recovery results are shown in figure 14. Here we see a decrease in front brake output over the first few heating snubs, and subsequently a large increase in front brake output that persists through the hot stop, cooling stops, and into post fade performance. Given the previous discussion regarding the requirements of FMVSS 135, any vehicle equipped with asbestos friction materials, or other fiber reinforced friction materials sharing a tendency to increase in output as a result of exposure to the fade heat cycle temperatures would fail the requirement of FMVSS 135.

Since the changes in front brake output observed in these tests seem to occur relatively early in the heating cycle, minor changes in the length of the fade heating cycle may not substantially change the hot stop performance of current motor vehicles. Given the test information gathered and reported here, it seems obvious that the hot stop performance requirements of FMVSS 135 cannot be met unless the allowable pedal force limit is changed to a maximum of 500 N (112 pounds) and a single wheel lock up is not considered a failure.

TABLE 1.

ANALYTICAL CALCULATIONS FOR FMVSS 105 AND FMVSS 135 DURING THE HEATING CYCLE OF THE FADE SCHEDULE

FMVSS 105 - PROCEDURE

10 stops from 60 mph @ max. decel. between 5 ft/s/s and 15 ft/s/s

(i) 5 ft/s/s

(ii) 15 ft/s/s

FMVSS 135 - PROCEDURE

ALTERNATIVE 1 – 80 snubs @ 7.9 ft/s/s from 34.2 mph to 15.6 mph

ALTERNATIVE 2 – 15 snubs @ 9.8 ft/s/s using the minimum of (i) or (ii)

(i) 80% Vmax to 40% Vmax

(ii) 74.6 mph to 37.3 mph

	FMVSS 105	FMVSS 135
ENERGY (ft–lbf/lbm)	(i) 1202 (ii) 1202	(1) 2475 (2) 2090
POWER (hp/lbm)	(i) 0.1242 (ii) 0.3727	(1) 1.3032 (2) 0.6808

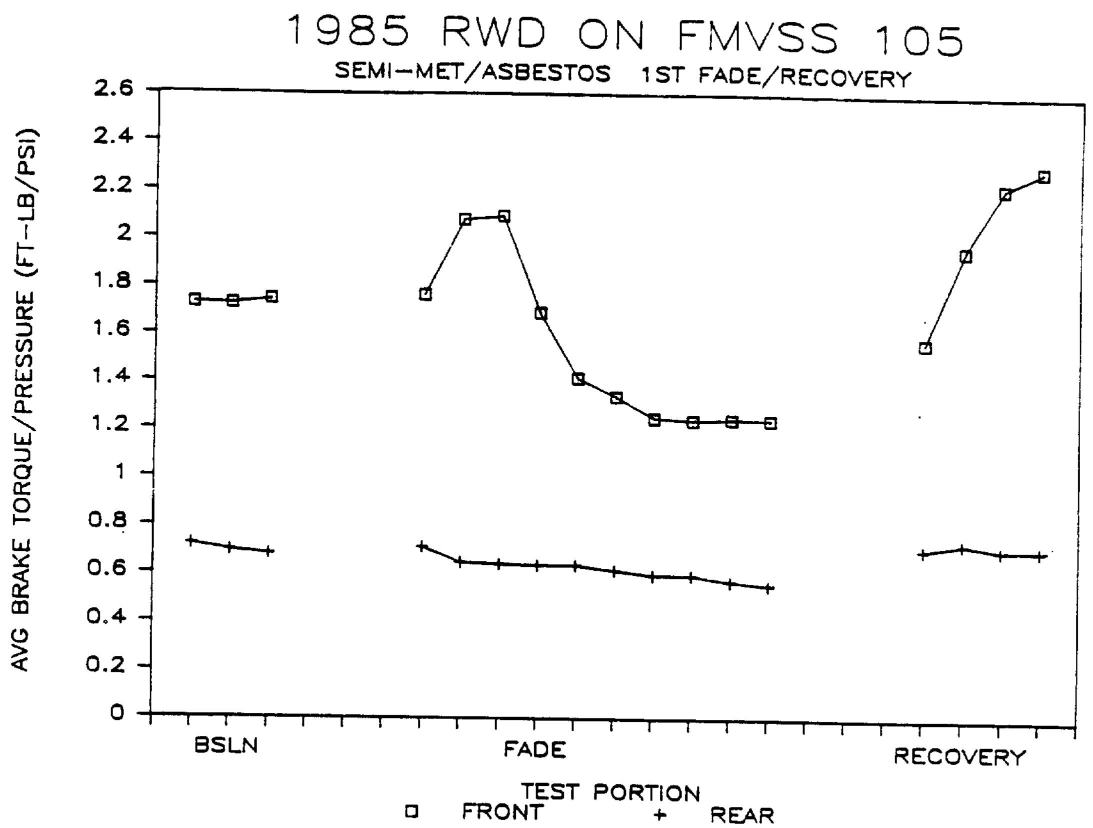
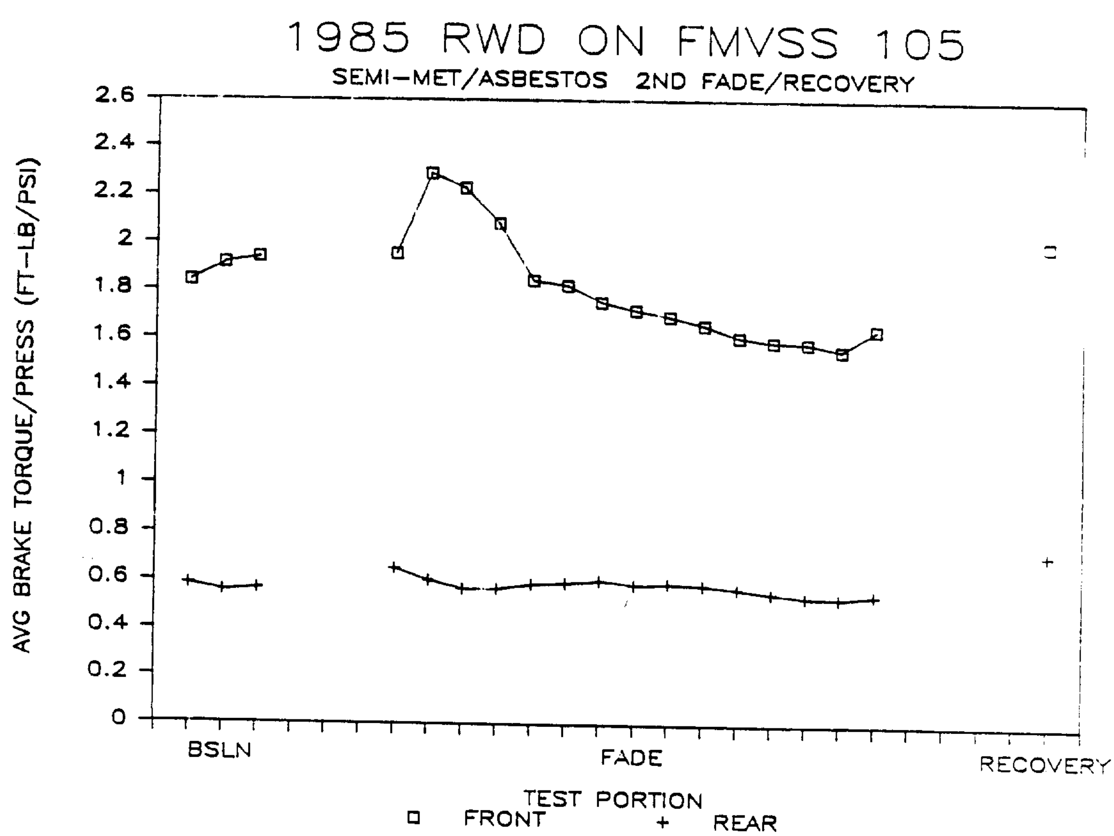


Figure 1



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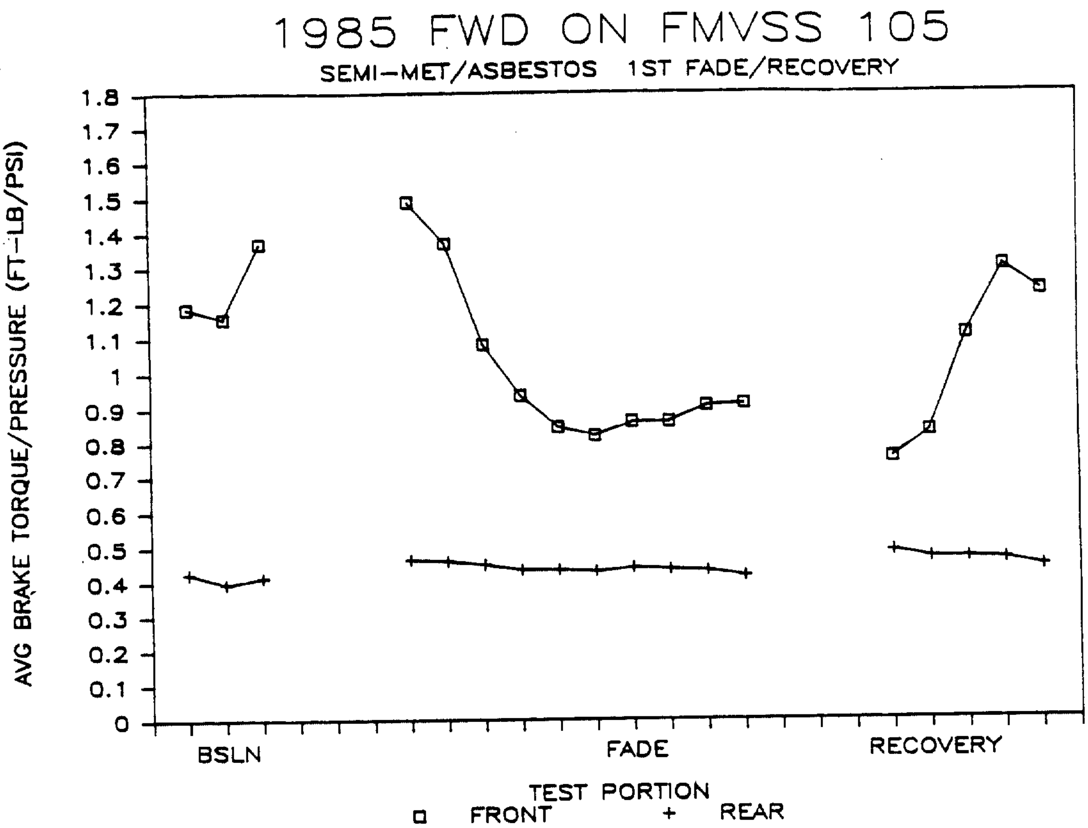

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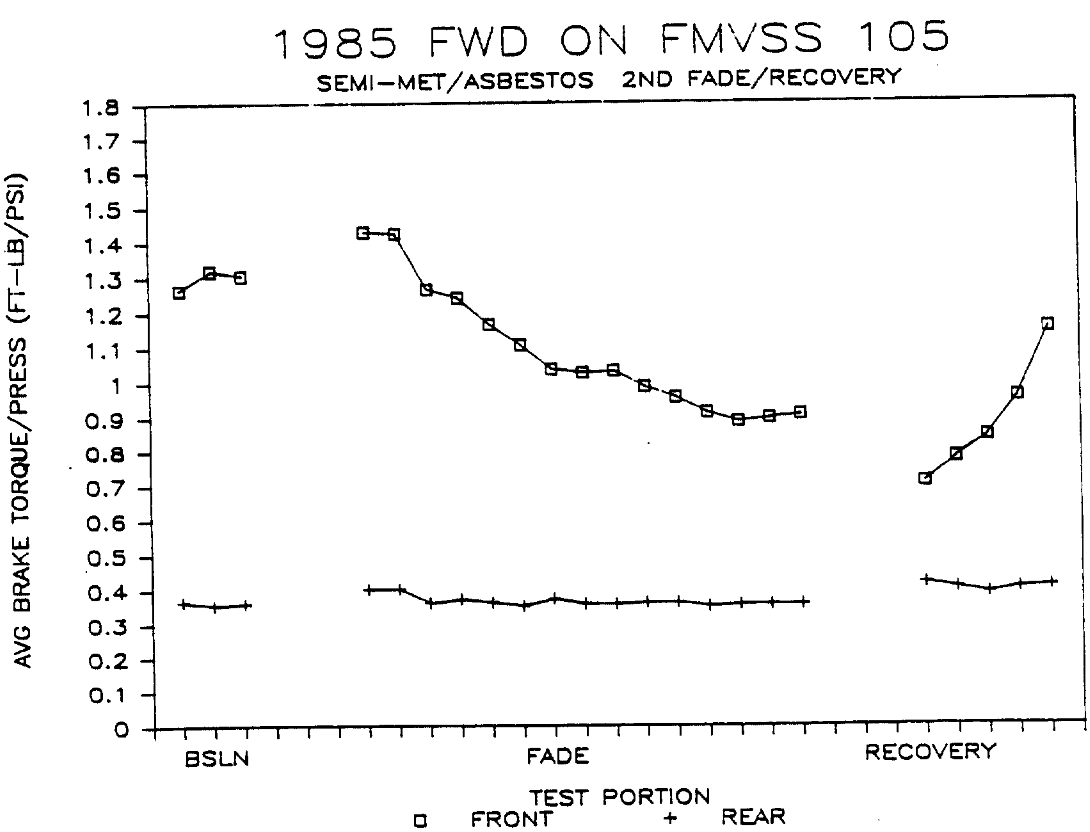

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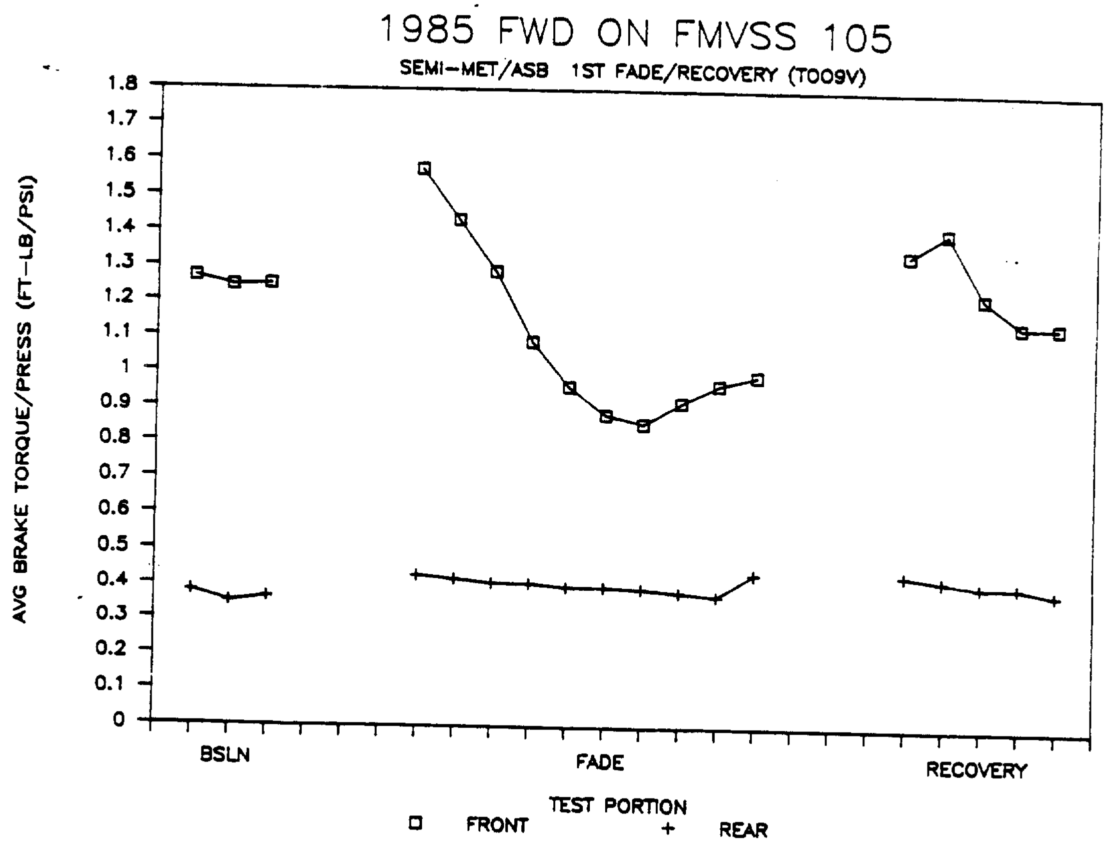

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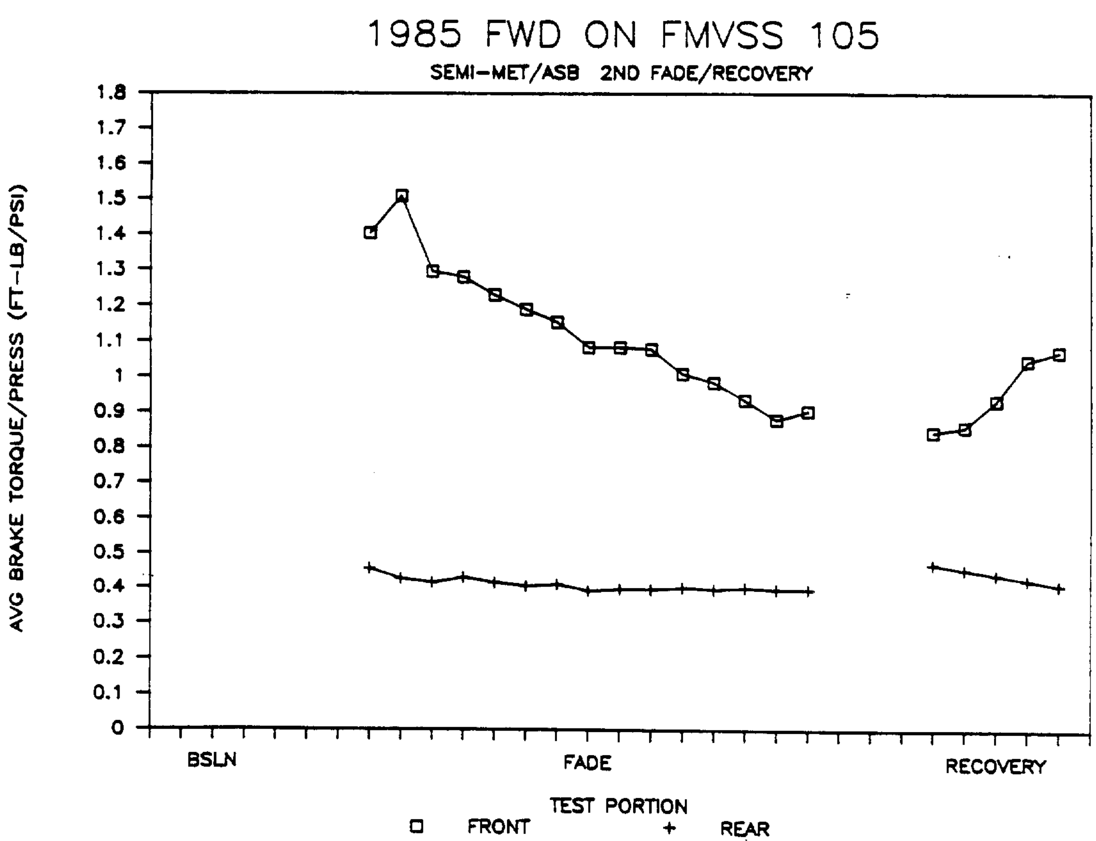

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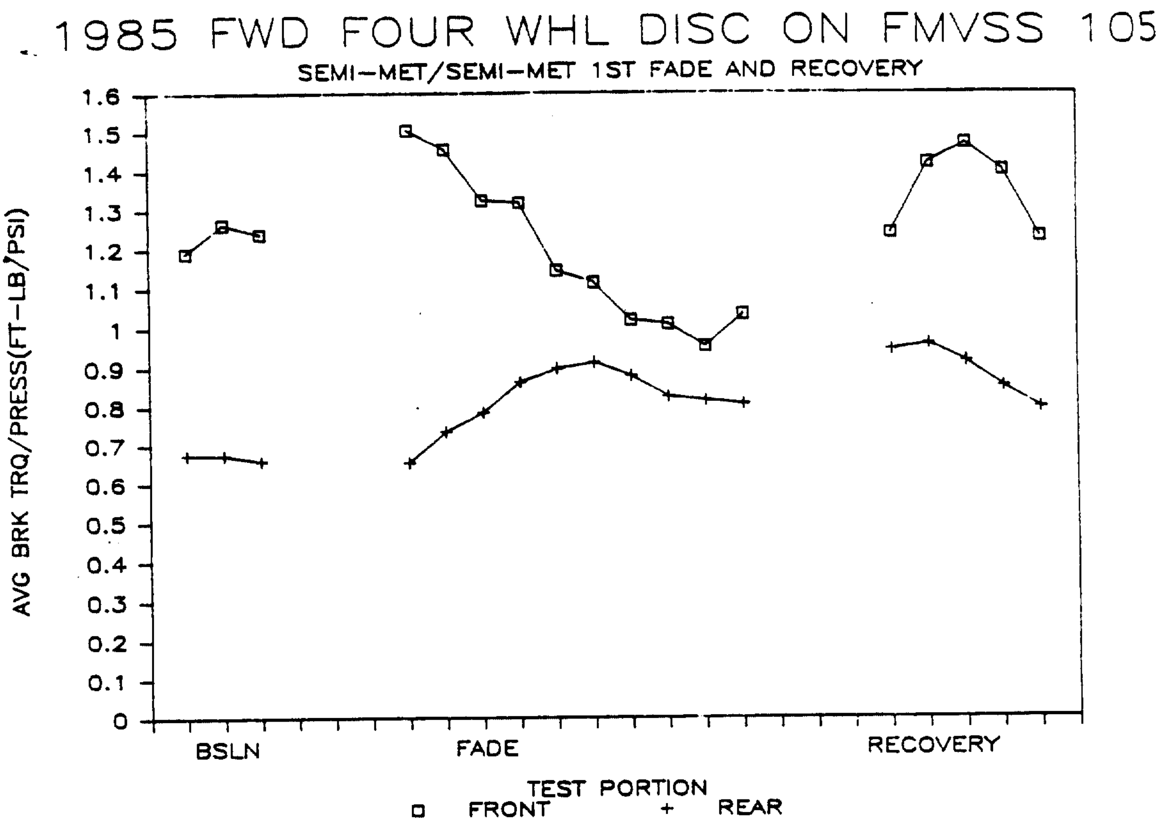


Figure 7

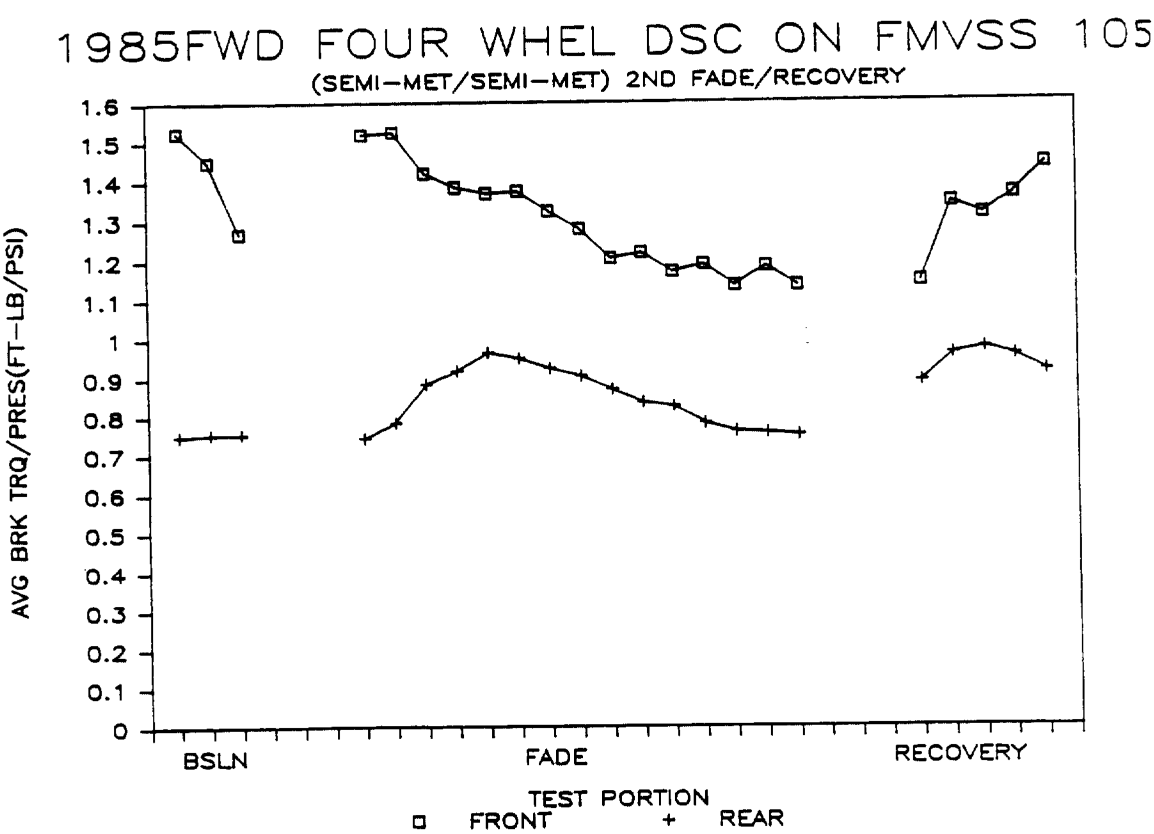
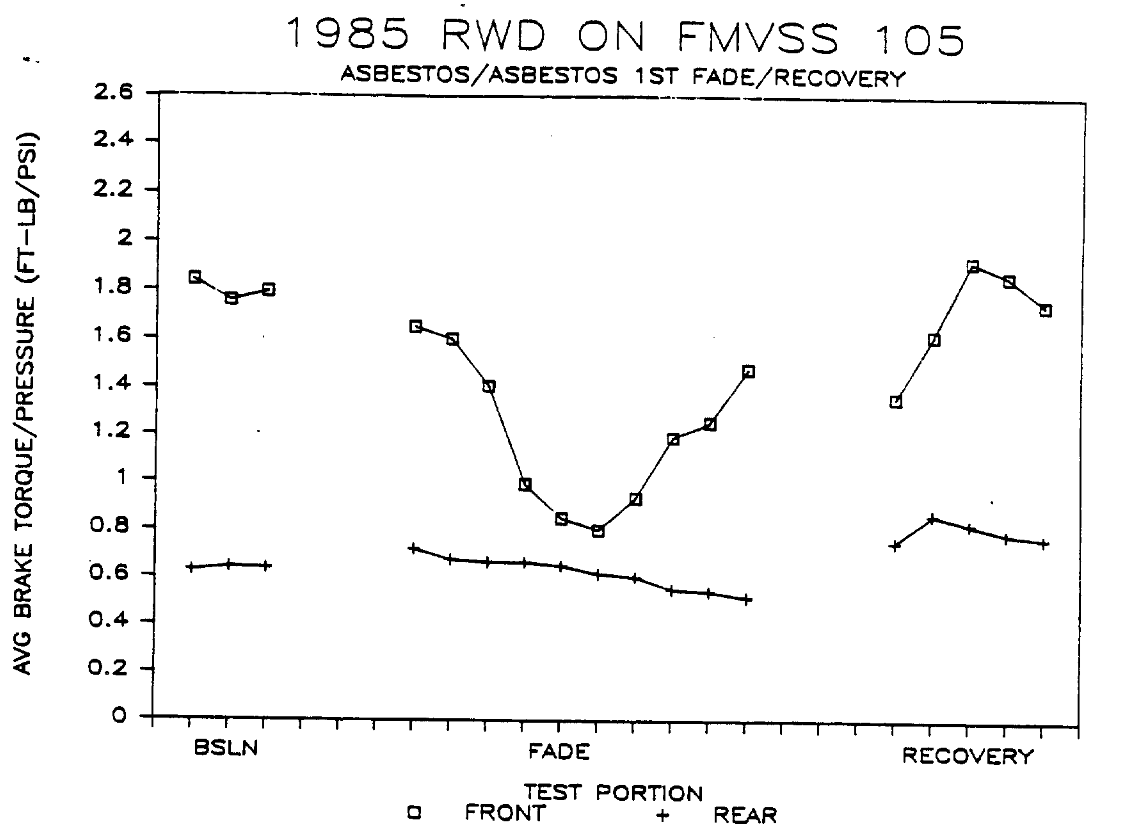


Figure 8



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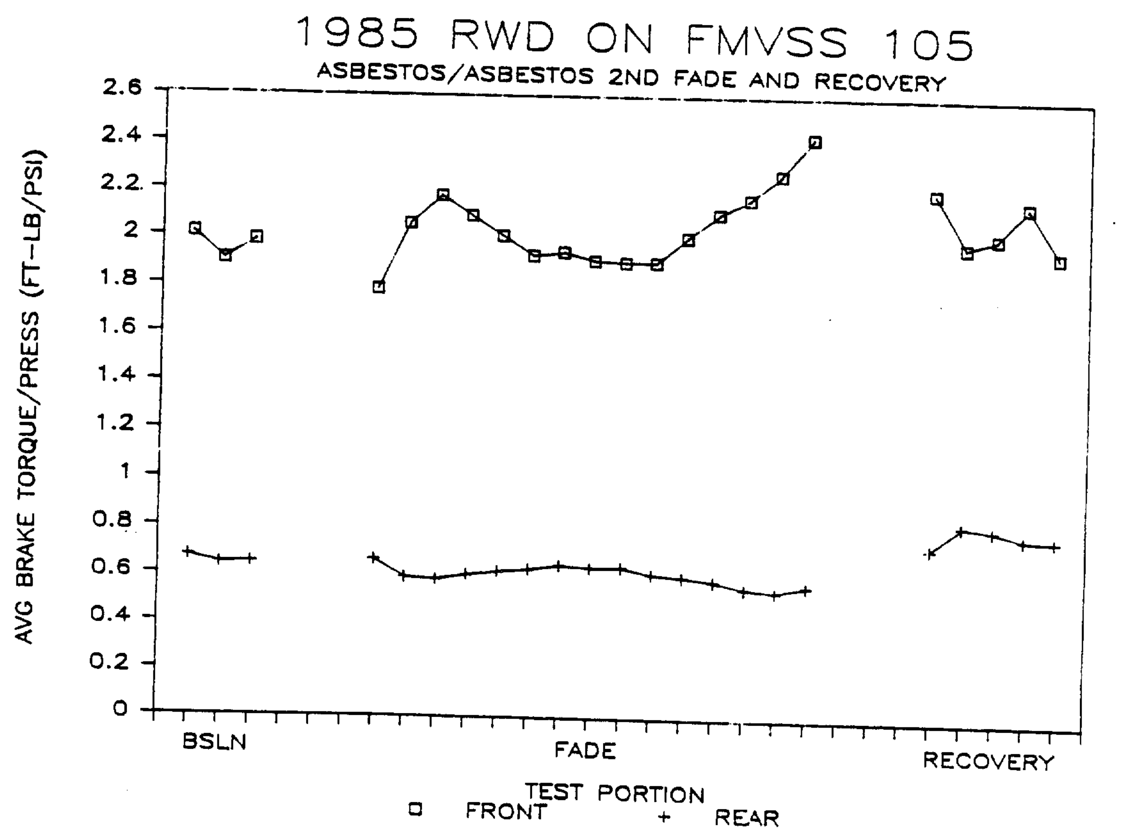

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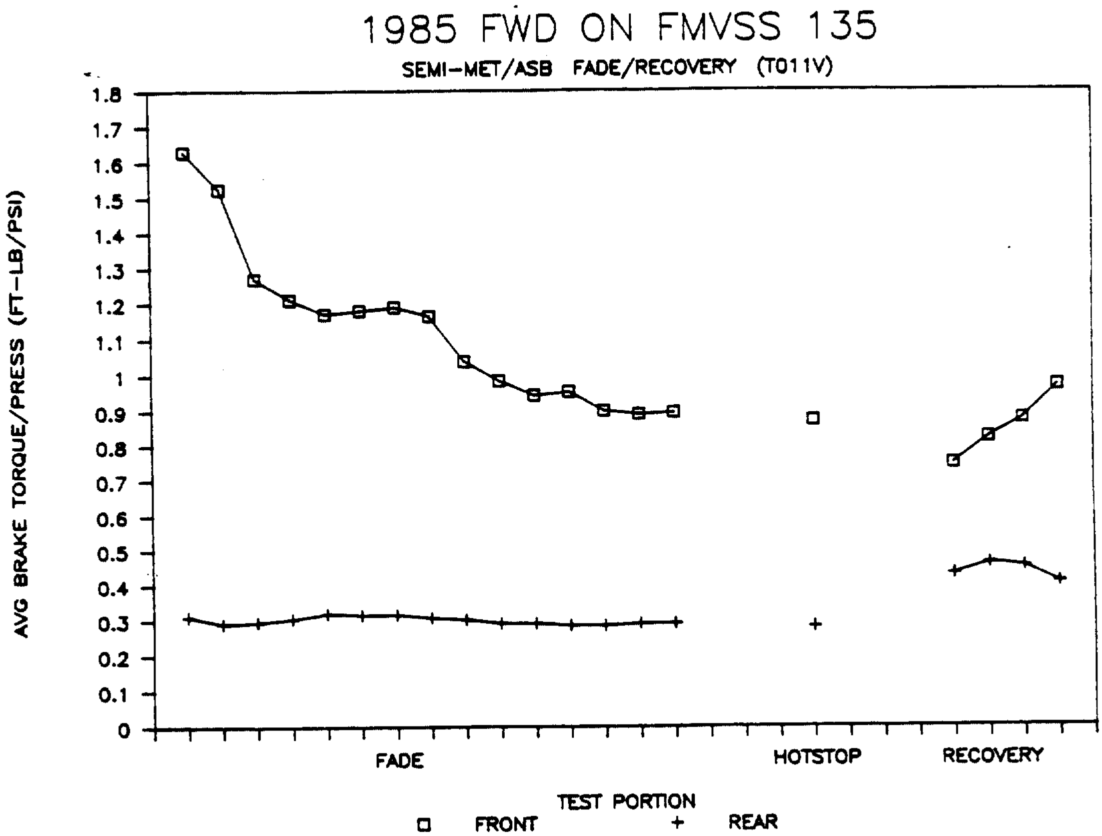

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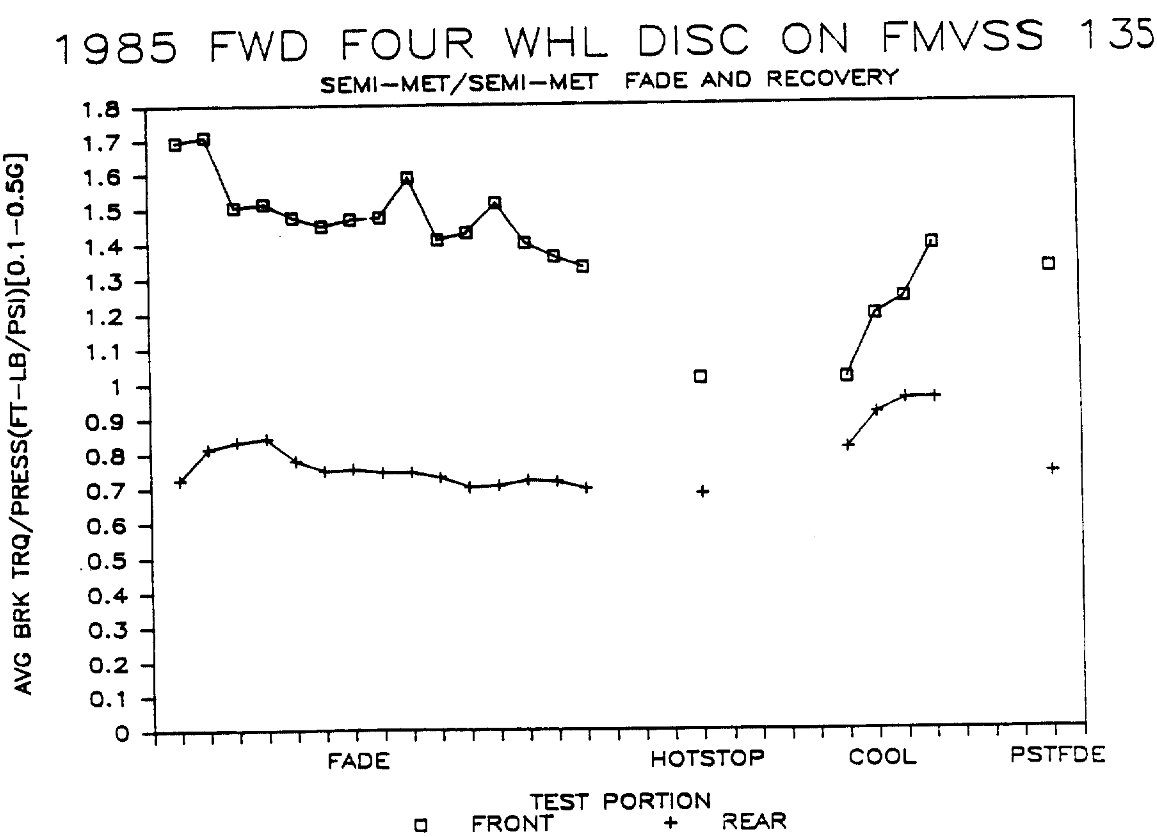

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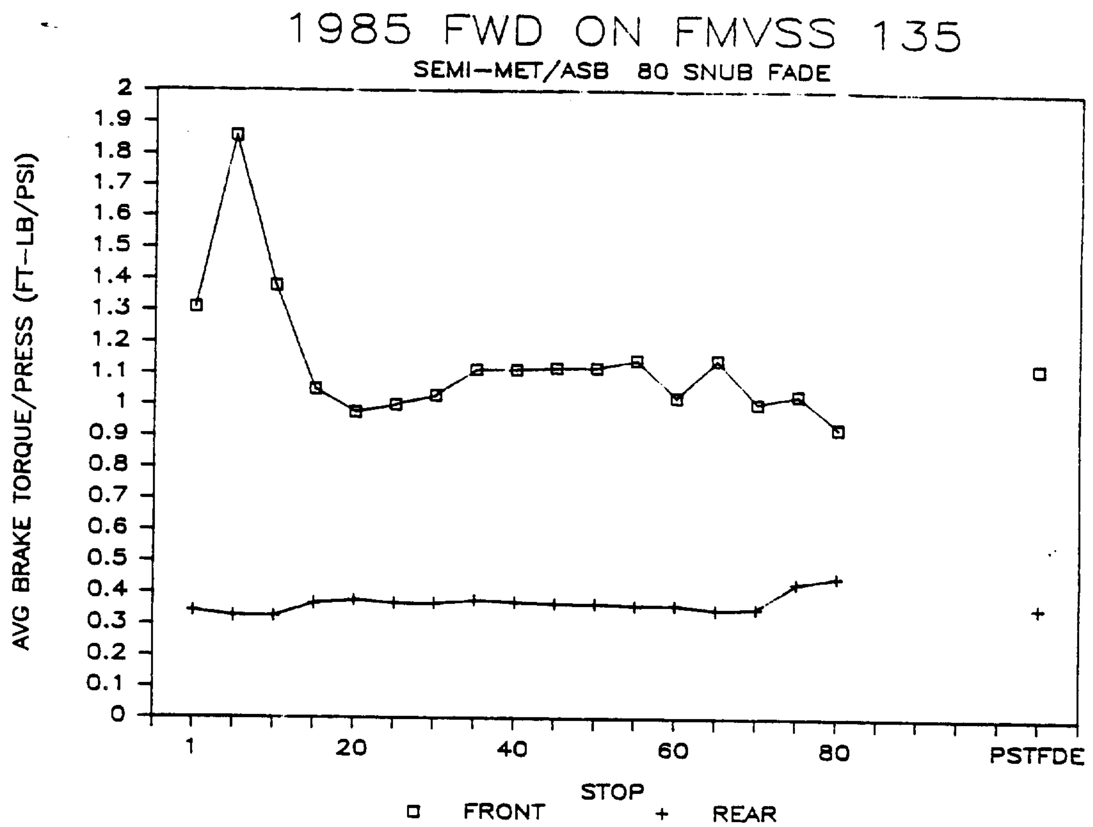

Figure 13

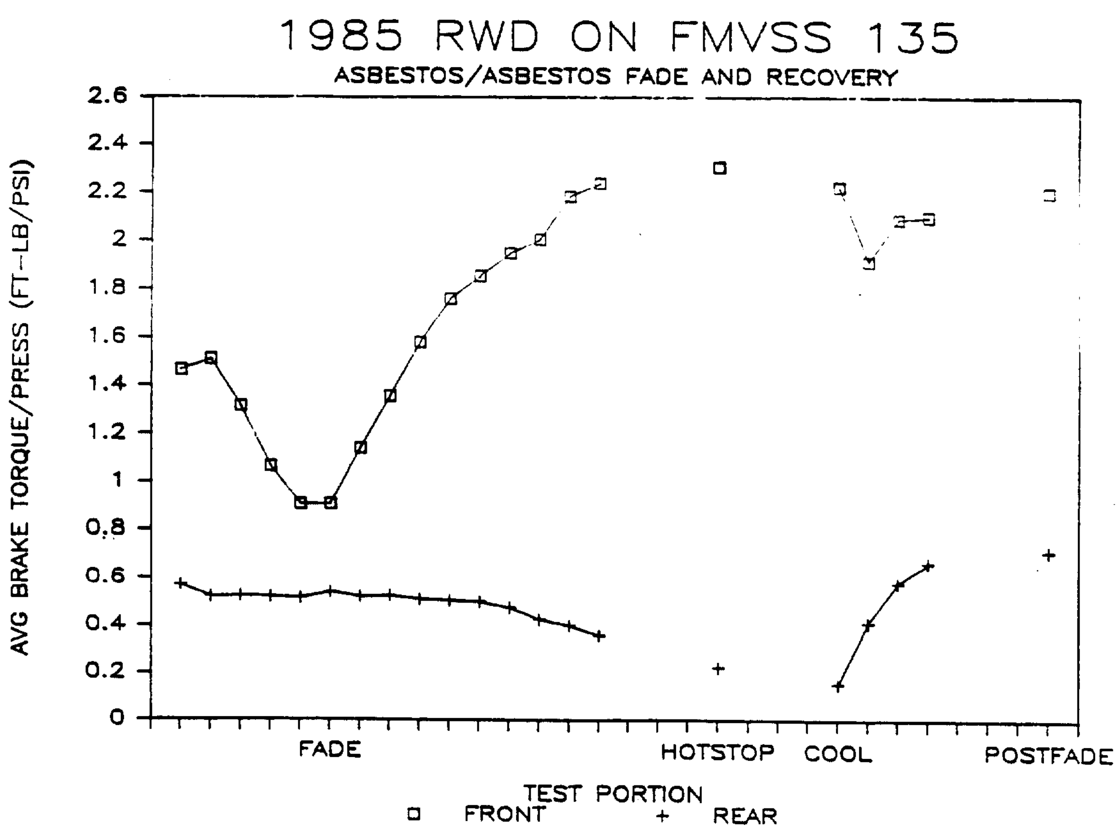

Figure 14

POST FADE RECOVERY EFFECTIVENESS

OBJECTIVE

The purpose of this appendix is to assess the post fade and recovery performance requirements of FMVSS 135 in terms of both stopping distances and allowable brake system effectiveness change relative to similar requirements in FMVSS 105 and draft proposal R.88.

CONCLUSIONS

1. The recovery performance requirements of the proposed FMVSS 135 limit brake system loss of effectiveness to less than 33% and prohibit gains in front brake output. However, gains in rear brake output are virtually unlimited.

2. FMVSS 105 contains an implicit recovery performance limit during the fifth stop. Based on nominal values of pedal force limits achieved during baseline stops, decreases in brake system effectiveness of 50% or more are permitted. Likewise, increases in brake system effectiveness of more than 300% are allowed in FMVSS 105.

3. ECE Draft proposal R.88 permits decreases in brake system effectiveness of the order of 35.8% and virtually unlimited increases.

4. GM tests suggest that the requirements of both R.88 and FMVSS 135 regarding loss of effectiveness would be difficult to meet with semi-metallic friction material equipped front disc brakes. Substantial increases in brake cooling rates would be required to achieve performance levels consistent with the requirements of FMVSS 135.

RECOMMENDATIONS

1. Since recovery performance is very dependent upon the fade heating cycle to which the brakes are subjected, NHTSA should establish the heating cycle first, then consider the implications of that cycle on achievable recovery performance before establishing the specific requirements for recovery.

2. The recovery performance should be related to a baseline stop or snub check conducted just prior to the heating cycles, as in FMVSS 105 or the proposed R.88, rather than to the performance in the cold effectiveness test.

3. The maximum pedal force limit for the post fade effectiveness test (after four recovery stops) should be established in the form used in FMVSS 105, i.e. a specific force increment over the average force measured during the baseline checks. (20 pounds (90 N) over the average is allowed in FMVSS 105.)

4. A minimum pedal force limit of 10 pounds (45 N) in the post fade effectiveness test should be established as the only over-recovery performance requirement.

4. An FMVSS 105 equivalent recovery performance stopping distance greater than 443 feet (133 m) should be adopted. (443 ft accounts for the difference in speed between the two procedures, but not the lower pedal force of FMVSS 135.)

DISCUSSION

At the outset, GM draws the agency's attention to a discrepancy in the Notice regarding recovery pedal force. In S5.1.3.2 the notice reads "with a pedal force <u>equal to</u> the average pedal force on the shortest cold effectiveness stop.." In the corresponding test procedure section, S7.11.4, reference is made to S7.11.2, where the language is: "..at a pedal force not greater than the mean pedal force..." S7.11.2 covers the hot stop, and in the preamble, the agency describes hot stop test condition as "..allowable pedal force could not exceed the mean pedal force...", thereby giving further insight into the agency's intent for hot stop. However the intent is still undefined for recovery. Since the agency has proposed an "over-recovery" minimum stopping distance limit as well as a maximum allowable stopping distance, the implication exists that the agency meant equal to for recovery, because otherwise the minimum stopping distance (over-recovery limit) could easily be exceeded by the test driver reducing the apply force. In any event, GM's comments which follow assume the agency intended "equal to".

The proposed FMVSS 135 contains a recovery or post fade effectiveness requirement that calls for performance assessment in a 100 km/h (62.1 mph) test following the four cooling stops in the fade and recovery portion of the proposed standard. The implications of this requirement can best be understood by discussing the maximum stopping distance allowed, and by determining the maximum allowable change in brake system effectiveness that is implicitly specified.

As noted in Appendix 26, Fade Hot Stop Tests, the fade and recovery portion of FMVSS 135 proposes two alternatives for heating sequence, 15 snubs at 30 seconds interval or 80 snubs based on SAE J-1247, followed by a hot stop, four cooling stops, and a post fade effectiveness test. The post fade effectiveness test calls for achieving a stopping distance less than or equal to the best cold effectiveness stop divided by 0.70 and more than or equal to the best cold effectiveness stop divided by 1.20. This requirement sets both an upper and lower bound on the stopping distance allowed. Like all other portions of the fade and recovery portion of FMVSS 135, this test is to be conducted with the vehicle in the GVW loading condition.

The minimum permissible burnished cold effectiveness brake performance, in terms of maximum allowable stopping distance, is 65 m (214 feet) from 100 km/h (62.1 mph). Assuming a 0.60 second brake system reaction time, this is equivalent to a minimum average deceleration rate of 0.70g (22.54 ft/s^2, 6.86 m/s^2). If a specific test vehicle just meets this requirement, then the post fade recovery requirement under FMVSS 135 would require this vehicle to be able to stop from 100 km/h (62.1 mph) within the interval of not shorter than 54 m (178 feet) but not longer than 93.3 m (306 feet). These values are the limit of burnished brake performance divided by 1.20 and 0.70 respectively, and are equivalent to minimum average deceleration rates of 0.86g and 0.47g, assuming the same 0.6 second brake system reaction time.

Since the applied pedal force is limited precisely to the mean value obtained during the best burnished brake test, the percentage change in required deceleration is exactly equal to the percentage change in brake system effectiveness permitted. Thus if the burnished brake test requires a minimum average deceleration of 0.7g just meeting the 65 m (214 feet) stopping distance requirement, and the post fade test requires a minimum average deceleration of 0.47g, then the allowed reduction in brake system effectiveness is given by (0.70 - 0.47)/0.70 or 32.9%. Likewise, the maximum percentage increase in brake system effectiveness is limited to (0.86 - 0.70)/0.70 or 22.9%. However, the degree of increase is misleading, as the no wheel lock condition in FMVSS 135 would preclude <u>any</u> of the allowed increase to occur in the front brakes.

To explain again, the best cold effectiveness stop will be obtained with the vehicle loaded to the GVW condition, which for virtually all vehicles is a front axle limited braking condition. If the driver is properly conducting the vehicle test in this loading condition, the stopping distance is limited by the front tire to road adhesion. This means that during the subsequent post fade effectiveness test, application of the same pedal force will produce a front wheel lock when any increase in front brake specific torque has occurred as a result of exposure to the fade, hot stop, and cooling stops procedure. Thus, the over-recovery limit of 22.9% increase in brake system effectiveness is condditional in that the total system effectiveness is allowed to increase to this degree, but only if no increase occurs in the front brakes. Since the rear brakes are typically doing less than 20 percent of the total brake work in the typical vehicle, this means a more than 100% increase in rear brake output is permitted, but no increase in front output is allowed for a vehicle that just meets the cold effectiveness requirement.

With the relatively high temperature and energy exposure of the brake elements during the proposed fade heating sequences, the friction materials may demonstrate in-stop fade and/or in-stop increases in output; the latter resulting in wheel lock up during the recovery stop at the proposed pedal force limit.

FMVSS 105 contains a recovery requirement following the first and second fade heating cycles. The first four stops of the five stop recovery test in FMVSS 105 do not restrict pedal effort to a level below the 150 pound (667 N) limit of other test portions. The fifth recovery stop of FMVSS 105 (which would be directly analogous to the recovery performance test of FMVSS 135) specifies that the vehicle shall achieve a deceleration of .31g (10 ft/sec^2, 3.04 m/s^2) from 30 mph (48.3 km/h). For this stop, the pedal force is limited to a maximum of 20 pounds more than the average control force from the baseline checks, and a minimum of; a) the average control force for the baseline check minus 10 pounds (45 N), or b) the average control force for the baseline check times 0.60, whichever is lower, but in no case less than 10 pounds. The baseline checks consist of three stops from 30 miles per hour at a deceleration rate of 10 ft/sec^2 with the applied pedal force between 10 pounds (45 N) and 60 pounds (267 N) inclusive.

Given the above stipulations of FMVSS 105, what then are the performance levels required in recovery stop following the cooling stops and how do they limit the change in brake system effectiveness? Assume the test vehicle achieves the baseline performance levels at an average pedal force of 20 pounds (90 N). (This value is taken from the GM tests run for this response, and is typical for power brake equipped vehicles.) This means that the post fade pedal force limits are not to be more than 40 pounds (178 N), and not less than 10 pounds (45 N). Since the pedal force deceleration relationship is nominally linear in this region, i.e., no booster runout is encountered, then the allowable increase in pedal effort (from 20 pounds to 40 pounds, 90 to 178 N) is equivalent to a 50% reduction in brake system effectiveness. Likewise, a minimum pedal effort of 10 pounds (45 N) during the post fade stop when compared to the 20 pounds (90 N) baseline value would suggest that a two fold increase in brake system effectiveness is permitted by FMVSS 105.

The deceleration requirement of FMVSS 105 during recovery stops i.e., 0.31g (10 ft/sec^2, 3.04 m/s^2) is less than 66% of the 0.47g (15.13 ft/s^2, 4.61 m/s^2) minimum average deceleration required in FMVSS 135 during post fade effectiveness. Likewise, the test speed in the FMVSS 105 recovery stop is only 30 mph (48.3 km/h) and not 100 km/h (62.1 mph) as in FMVSS 135. Post fade stopping distance under the condition of FMVSS 135 which would be equivalent to FMVSS 105 adjusted to 100 km/h would be 135 m (443 feet), assuming the same 0.60 second reaction time. The 93 m (305 feet) allowed in FMVSS 135 (maximum) is less than 69% of this value. Additional distance must be added to this 443 feet to account for the increased stringency of the limited pedal application force stipulated by FMVSS 135.

An additional point that increases the stringency of FMVSS 135 is the fact that performance limits are established on the basis of the best burnished stop performance in FMVSS 135, while FMVSS 105 bases performance limits during the fade schedule on baseline checks performed immediately prior to the fade heating cycle. Likewise, R.88 uses baseline checks immediately prior to the fade heating cycle. In the FMVSS 135 procedure, tests of adhesion utilization, high speed effectiveness, engine off effectiveness, cold effectiveness at LLV, LLV high speed tests, LLV engine off tests, partial systems at LLV and GVW, failed anti-lock, and failed power assist are all run between the burnished brake performance at GVW and the fade sequence. As the GM test results have shown, substantial conditioning of the brake system continues to occur throughout the certification procedure. To tie brake system performance after fade and cooling stops to performance levels demonstrated in tests much earlier in the test sequence is inappropriate and would require a substantial increase in performance stability over that of FMVSS 105 or R.88. In order to preserve the form, and substantive stringency, the agency should base post fade recovery performance on a short series of baseline checks immediately prior to the fade heating cycles.

Draft proposal R.88 also includes a recovery performance test similar in form to that embodied in FMVSS 135, but the R.88 requirement states that a pedal force <u>not greater than</u> the mean pedal force used in the best GVW burnished brake stop be used in the recovery performance stop. No minimum pedal force limit is specified.

Recall that the cold or burnished brake performance limit of R.88 is 77 m (252.6 feet) from 100 km/hr (62.1 mph). Using the reaction time multiplier of 0.10 (as used in R.88 and ECE R13), the maximum recovery stopping distance in R.88 is 105.7 m (346.8 feet). Based on a 0.60 second reaction time this is equivalent to a deceleration rate of 0.41g (13.2 ft/s^2, 4.0 m/s^2) as compared to the 0.64g (20.6 ft/s^2, 6.27 m/s^2) required in the cold effectiveness stop. This means the brake system loss of effectiveness is limited to 35.8% at this performance level Increases in brake system effectiveness are not limited as is appropriate for an application force specified as "not greater than" a given number.

The GM tests of both semi-metallic and asbestos front disc brake friction materials indicate that the requirements of both FMVSS 135 and R.88 (particularly the requirement to meet the stopping distance with no increase in pedal force over the best cold effectiveness test pedal force) are not achievable with current brake systems. Brake friction materials that demonstrate substantial increases in output as a result of fade exposure would have little difficulty meeting the requirements of R.88, but semi-metallic friction materials would be marginal. Since most of the change in brake system output occurs during the first few stops of the fade heating cycle, significantly larger front brakes would be required to reduce the temperatures to levels that would permit compliance to FMVSS 135 and R.88.

It should be noted that ECE R13 does not even contain a recovery performance limit. The R.88 recovery performance procedure was established during discussions by the GRRF ad hoc group on brake standardization, borrowed from FMVSS 105. No data existed relating the proposed recovery performance requirement to the fade heating cycle of R.88, nor to the cycles proposed in FMVSS 135. It seems appropriate, therefore, to use the form of the 105 requirement, including a specified allowable pedal force increase, and establish the actual performance level after the heating cycle is settled.

SPIKE STOPS AND FINAL EFFECTIVENESS TEST

OBJECTIVE:

The purpose of this Appendix is summarize an analysis of both the spike stop and the final effectiveness tests requirements contained in FMVSS 135.

CONCLUSIONS:

1. Spike stops address the structural integrity of the vehicle components such as suspension, tires and wheels rather than evaluating the brake system performance.

2. If the spike stops are eliminated, the final effectiveness stops become redundant because the post fade recovery test will essentially check the end effect of the FMVSS 135 test procedure.

RECOMMENDATION:

1. In the interest of harmonization, the NHTSA should eliminate both the spike stops and final effectiveness provisions of FMVSS 135.

DISCUSSION:

The NHTSA has retained the spike stop requirement and a modified final effectiveness requirement from FMVSS 105 in FMVSS 135. These requirements have never been a part of ECE R13 and were not included in the performance criteria of ECE R.88.

The original basis for the spike stops requirement was that an existing SAE procedure used such spike stops to "proof test" vehicles equipped with drum brakes at all four wheel positions. The original SAE procedure was aimed at validating the hoop strength of the drum when large force inputs were delivered with spike stops. In addition, these spike stops could on occasion produce bent shoes in drum brake assemblies on the front axle.

With the virtually universal application of disc brakes on the front axle of vehicles during the 70's, the need for such spike stops was eliminated. In current designs, the disc brake rotor is clamped in compression, and clamping loads to produce wheel lock up are much lower than the compressive strength of the cast iron rotors. The drum brakes used on the rear axle are exposed to much smaller loads at wheel lock up and no major problems associated with spike stop performance have been noted for many years.

If the spike stops are intended to verify the structural integrity of the hydraulic system, pedal mechanism and attachment of the master cylinder to the dash board, this objective could be achieved by performing a static test at the beginning of the test sequence using a pedal force in excess of 500 N (112 lbs). All vehicles tested by GM normally receive such static tests to assure the system has been properly bled and contains no entrained air within the hydraulic system.

Given that the agency accepts the arguments for eliminating spike stops, the need for a final effectiveness test no longer exists. It is GM's view that for modern front disc systems, spike stops do not subject the brakes to significant work since the vehicle's kinetic energy is absorbed by the sliding tires. Based on that observation, the need for final effectiveness stops is met by the post fade/recovery performance requirement. Thus, the final effectiveness test is redundant, and adds no new information regarding brake system performance regardless of spike stops. GM strongly supports the view of the GRRF that the spike stops and the final effectiveness test are not necessary, and should be dropped in the interest of harmonization.

SUMMARY OF ENGINEERING CONCLUSIONS

1) The performance requirements of FMVSS 135 for stopping distance and brake balance conflict to such an extent that most vehicles meeting both FMVSS 105 and ECE R13 would not comply with FMVSS 135.

2) The performance requirements of FMVSS 135 for high speed tests, partial systems tests, no power tests, engine off tests, failed anti-lock tests, failed variable proportioner tests, parking brake tests, fade hot stop and fade recovery tests are all more stringent than FMVSS 105, ECE R13, and draft proposal R.88.

3) Current production vehicles are limited in stopping distance capability by both brake balance and tire to road peak traction. The characteristics of both tires and brakes change from a pre-burnished ("green") condition to a burnished condition. Stringent pre-burnished requirements result in compromised vehicle performance in the burnished condition.

4) The stopping distance requirements of FMVSS 135 must be consistent with the emphasis on front axle limited brake balance. If a vehicle test for brake balance is included, an additional increase in stopping distance is required beyond that necessitated by balance requirement applied to the nominal vehicle design. Further, a brake balance variability of at least 10 percentage points must be accommodated in the stopping distance requirements. In addition, an adjustment must be included for the reduced number of attempts permitted at each test requirement.

5) The performance requirements of FMVSS 135 will virtually preclude manual brake systems and front-rear partial system splits, inhibit the introduction of variable proportioning and deter the introduction of current and future integrated technology anti-lock brake systems.

6) A brake system reaction time of 0.60 seconds is typical for FMVSS testing. Using this reaction time, a stopping distance of 187.2 m (614 feet) for partial systems and no power tests in FMVSS 135 is equivalent to the current requirements of FMVSS 105. Likewise, an engine-off stopping distance of 77 m (252.6 feet) is equivalent to the current requirements.

7) If a procedure for measuring vehicle brake balance is to be adopted, it must be both repeatable and valid. The procedure of FMVSS 135, or a modified Swedish procedure, are inappropriate because they measure vehicle performance only at a single deceleration. The Road Transducer Pad (RTP) technology offers the highest potential for testing of brake balance, however additional development and evaluation are necessary to convince the international community of its utility.

8) The results of the NHTSA vehicle test program are not a suitable basis for establishing performance criteria in a brake standard. Neither the vehicle population studied, the test practices employed, nor the analytical techniques used are acceptable for this purpose.

9) The unbounded 80% Vmax requirement of FMVSS 135 is unrealistic in terms of both test practice and customer driving habits.

10) Both of the fade heating cycle alternatives proposed in FMVSS 135 are unrealistic. Compared to the worst case customer demands (a GVW descent of Pikes Peak) both heating cycles of FMVSS 135

are excessive (as is the fade heating cycle of FMVSS 105). Both GM and NHTSA vehicle tests show fade occurs at lower power levels than developed in any of these heating cycles. The hot stop and recovery requirements of FMVSS 135 are each more demanding than the corresponding requirements in FMVSS 105. When combined with the more demanding fade heat cycles of FMVSS 135, these requirements would force substantial modification to existing vehicle designs.

11) Specification of brake test surface based on slide coefficients measured with an obsolete traction tire is inappropriate.

COMMENTS ON NHTSA REGULATORY EVALUATION

DESCRIPTION

This Appendix contains GM comments on certain portions of the Preliminary Regulatory Evaluation on "International Braking Standard for Passenger Cars" prepared by NHTSA's Plans and Programs Office of Planning and Analysis. Comments are indexed to the section and page number in the Regulatory Evaluation. Selected portions of the Preamble of Notice 1 are reviewed as well.

DISCUSSION

The agency describes the proposed standard as follows in the Notice, page 19745 of the Federal Register, Vol. 50, No. 91:

> The new standard differs from the passenger car provisions of Standard No. 105, Hydraulic Brake Systems, primarily in that its test procedure would be shorter.

This statement is misleading, as is apparent from these GM comments. The fact that the test procedure is somewhat shorter than that in Standard 105 is incidental. The primary differences are that the proposed FMVSS 135 requires front biased brake balance and imposes a level of stringency that is not only more severe than FMVSS 105 but is demonstrably unachievable for most vehicle.

On page II-3 NHTSA recognizes the significance of revisions in the early part of the test procedure as they would affect the comparability to the ECE draft (R.88/R.94), saying:

> If the NHTSA were to adopt a standard with major changes in the early part of the harmonized test procedure, the rest of the procedure might no longer be comparable in terms of stringency to the original ECE draft.

This is a correct observation, but the actual drafting of the proposed standard has not reflected the admonition. Specifically, the proposed preburnish effectiveness requirements are in conflict with the R.88 draft and affect the performance in subsequent test sequences. This is discussed in detail in Appendix 16, Pre-burnished Brake Effectiveness.

Later on page II-3 the agency says:

> The bulk of the proposed standard's test procedure is consistent with the ECE draft. Adoption of the proposed standard would be a major step toward harmonization and would make it much easier for manufacturers to build vehicles for the world market.

The proposed FMVSS 135 does indeed utilize much of the form of a standard that could lead to harmonization. The comments of GM, the MVMA, the ECE GRRF, and others, should make it clear that considerable revision is necessary however, before a standard is achieved that "would make it much easier for manufacturers to build vehicles for the world market". GM does support the concept of harmonization to reach that stated goal, and urges the agency to proceed accordingly.

Section III of the regulatory evaluation details the differences between FMVSS 135 and FMVSS 105. The description of the differences is generally accurate.

On pages IV-1 to IV-11, the agency describes some aspects of cost impact of the proposed test procedure. The initial reaction to this section was one of disappointment that the actual cost figures upon which NHTSA made its comparison were deemed to be proprietary and hence not available for examination. However, from the manufacturer's standpoint, the costs of the compliance tests are small when compared to the costs of developing and manufacturing brake systems to meet different existing regulations, or developing and incorporating new complex hardware that would be necessary if the proposed standard could indeed be met at all.

Therefore, GM's only comment upon the detailed analysis of test costs is to remind the agency that costs of running compliance tests are but a small part of the total costs which may accrue if the rulemaking action does not lead to true harmonization and instead results in otherwise unnecessary design changes. Also, compliance tests costs are small compared to the economic savings that could be realized if harmonization can indeed be truly achieved.

On pages IV-12 to IV-14, the agency lists five test requirements that "may require modification or redesign of braking system components." These are:

-fully charged failed power assist
-partial failure test, fully depleted
-parking brake gradient hold
-adhesion utilization test
-fluid level checking without removing the cap

GM agrees that these test conditions will prompt brake system modification or redesign if promulgated in the existing form. However, we have three additional comments on this section:

1) The test results referred to by the agency in this section treat each test requirement individually. For instance, the report states on page IV-13 that 11 out of the 45 vehicles tested to the partial failure test for the fully depleted condition failed the test. In evaluating the significance of this observation, it is important to remember that the requirements of the proposed FMVSS 135, or any other brake system standard are very interdependent. Thus, altering a brake system to meet a requirement of one section of the standard may make it more difficult, or even impossible to meet other sections. The brake balance requirements of FMVSS 135 are a prime example. If some of the 34 vehicles that passed the test cited above did not meet the requirement to be front biased in all conditions, revising their brake balance to be front biased could very easily revise their performance to this test such that they would fail. More extensive discussions and supporting data addressing this issue appear in many appendices to these GM comments.

2) In most cases, the agency has characterized the brake system changes that might be required under the proposed standard as "minimal". This characterization does not reflect all the constraints within which manufacturers must design brakes. For example, the discussion of the partial system test on page IV-13 suggests that increased booster gain is a relatively easy solution to the problems. Increasing booster gain, whether by reducing master cylinder bore or increasing "mechanical advantage of the foot control" results in increased pedal travel for the necessary wheel cylinder displacement. The increased pedal travel is limited by two very real constraints: the position of the floor pan below the pedal, and the amount the driver can be expected to lift his foot (or is able to without interferences) above the accelerator pedal to engage the brake. Thus, for some cars, increasing booster gain may result in a major redesign not only of brake system components, but of driver seating position

and of major sheet metal components, etc. The potential costs of such redesign far exceed any characterization as "minimal".

3) Brake system equipment changes would be dictated by other requirements of the standard in addition to the five listed above. The overall stringency of some of the proposed requirements would necessitate significant revisions on many cars, and could not be met on others.

In the discussion of comparative stringency beginning on page V-6, the agency admits of four test conditions that make it difficult to make direct comparisons of stopping distances. These are initial speeds, brake conditioning, number of runs per condition, and wheel lockup criteria. Pedal force should be considered in that list as well, because a vehicle's performance to some test conditions such as partial system performance or failed power assist is likely to be pedal force limited.

After announcing on page V-6 that it is a straightforward calculation to adjust for initial speed, the agency published in table V-1 a comparison of the proposed FMVSS 135 stopping distances and the "adjusted for speed" FMVSS 105 stopping distances. This table indicates that the FMVSS 105 second effectiveness requirement adjusted only for speed is 66.6 m (218.5 ft), yet the agency proposed only allowing 65 m (213.3 ft). This shorter stopping distance is an actual increase in stringency <u>even if the test conditions were not changed</u>. No need for increasing this stringency has been demonstrated.

The agency comments on burnishing, at the end of page V-6, correctly indicate that burnishing can either increase or degrade the output of drum brakes. However, the changes in brake output from new to burnished have significant effect on brake balance, since disc and drum systems burnish at different rates (see Appendix 10, Brake Burnish). Therefore, tests conducted with the brakes in any condition less than fully burnished are conducted at a balance other than that intended by the designer.

The proposed test allows only 4 attempts to obtain the best performance in each test condition (instead of the 6 in FMVSS 105). This number originated in the harmonization discussions of the GRRF. The agency comments on page V-9 accurately recognize this as a slight increase in stringency. The agency then goes on to say:

> This would seem to be a desirable tightening of the requirements since any vehicle which would require more than four stops to achieve the proposed standards with a highly skilled driver would not likely yield satisfactory results in the hands of the relatively unskilled driving public.

Most vehicle tests to FMVSS 105 do in fact allow a full six attempts to achieve the required stopping distance. No evidence has been advanced to show that cars certified to FMVSS 105 do not yield satisfactory results in the hands of the driving public. The reduction of test attempts from 6 to 4 resulted from the harmonization discussions and was primarily an attempt to reduce the time and costs of running the tests. NHTSA's allegation quoted above is unfounded. The question of relative stringency effect of 4 vs 6 stops is discussed with supporting data in Appendix 15, Number of Attempts Allowed.

On page V-10, the agency says:

> The proposed harmonized procedure does not allow lock-up at any wheel at speeds at above 15 km/h. Since optimum braking occurs at the point of incipient wheel lock-up, skilled test drivers will attempt to avoid wheel lock-up during testing in

> any event. Thus, it is believed that this requirement would only affect stringency in the sense that it may "spoil" some of the test stops.

The agency has correctly suggested that the requirement for no wheel lockup during a stop would "spoil" some of the test stops. This could require a complete rebuild and retest of a certification test; a significant waste of time. It also has a measurable effect on the stopping distance test drivers achieve in actual tests. GM therefore has requested that tests wherein a skid is detected by the driver may be aborted without being counted as one of the four attempts. This issue is discussed in Appendix 15 as well.

Beginning on page V-10, the agency describes the testing it conducted to the proposed harmonized test procedure on a total of 45 cars. (It needs to be noted here that this procedure evolved during several GRRF ad hoc meetings during this testing period, and the procedure therefore varied considerably from the proposed FMVSS 135 procedure. GM has provided in depth comments on the testing program in Appendix 14, NHTSA Tests.) The agency then described four methods of analysis it used to examine equivalency between the proposal and FMVSS 105. The first method was simply the speed correction calculation discussed above.

The agency describes Method II as follows:

> Method II attempts to project a 95 percent confidence band of performance values based on the common mean of the 19 car sample that was tested to both FMVSS No. 105 and the proposed harmonized procedure, and the measured average system reaction time of 0.18 seconds. Paired test results were plotted along with the point representing system reaction time only. A 95 percent confidence

> interval about the harmonized mean was then determined at the FMVSS No. 105 performance mean. Straight lines were then plotted through the point representing the 95 percent confidence interval about the harmonized mean at the FMVSS No. 105 performance mean. The points of intersection of these lines with the FMVSS No. 105 performance requirements determine the band of equivalent performance levels for the proposed harmonized test.

We find the above description of Method II insufficient to determine what actually was done. However, as our Appendix 9, Brake System Reaction Time establishes with supporting data, 0.18 seconds is clearly insufficient and unrepresentative reaction time. Therefore, even if Method II has validity in concept, the numbers generated by it are incorrect for proper comparison of stringency.

Method III is described on page V-14 as follows:

> Method III determines the level of performance that would result in the same percentage of vehicles complying with the proposed harmonized procedure as projected for the corresponding FMVSS No. 105 test as derived from actual 105 compliance data. Test results from 55 cars tested to FMVSS 105 were used to determine a table of predictions of percent of vehicles complying with each 105 requirement.

There is a significant flaw in this method because it looks at each requirement separately, and assumes that a population of vehicles can pass individual requirements, ignoring all others. As discussed in more detail in Appendix 14, NHTSA Tests, a vehicle fails to comply with a safety standard, even if it fails just one requirement and passes all others. Because the brake system performance characteristics for a vehicle are very inter-dependent, vehicles may pass the requirement being examined, yet be unable to pass the complete standard, therefore skewing the data for the specific requirement. This is very significant when one considers that FMVSS 135 would require front biased brake balance. The description of Method III implies that data from a large sample of actual FMVSS 105 compliance tests were used for this comparison. Thus, the data must have been representative of the general American vehicle population. GM has a significant body of brake balance data for this population of vehicles, and finds that a very significant proportion of those vehicles would not pass the proposed front bias requirement. Thus, considering the relationship between brake balance and stopping distance discussed in Appendix 4, Brake Balance Influence on Stopping Distance, these vehicles do not represent achievable performance under FMVSS 135 constraints. Therefore, the results of Method III cannot be relied upon.

Method IV is described on page V-15 as follows:

> Method IV statistically analyzed the performance figures for the cars tested to FMVSS No. 105 to determine the average performance for the group of vehicles, and the standard deviation of the data. This performance was compared to the performance required by FMVSS No. 105 and the distance between the average and the required performance was expressed in terms of the standard deviation. Then, the performance data for the harmonized procedure were similarly analyzed, and the standard deviation for that data obtained. The 105 equivalent requirement was then calculated by adding the same margin of compliance (in terms of standard deviation of data) as was found in the 105 tests.

GM performed a mathematical analysis of this method soon after it was presented by a member of the NHTSA staff at the 1984 SAE Congress. At this time the vehicle test population included 19 vehicles reported in the third of the four NHTSA test reports. The comments below are based on that analysis. If the agency applied this technique to an additional quantity of vehicles, the potential exists for revised conclusions. GM has not had the time to extend this exercise to a larger number of cars.

With the above caveat, we find that this analysis is flawed for several significant reasons discussed below:

1) Our analysis of brake balance for the 19 vehicles tested indicates that 26% of them would not meet the front bias requirement of the proposed FMVSS 135, and another 16% are marginal. (This analysis of NHTSA test data is described in Appendix 14, NHTSA Tests.) The significance of this is that the stopping capability for these vehicles is not necessarily indicative of the stopping capability for the same vehicle if it had to meet the entire FMVSS 135 standard. NHTSA addressed this issue on page V-16, saying,

> ...the average stopping distances for only those cars which also passed the proposed adhesion utilization requirements were compared with the average stopping distances of the entire sample. All but five of the 19 cars tested complied with the proposed adhesion utilization requirements. The average service brake stopping distance of the 14 cars that did comply was 0.17 percent longer than the average stopping distance of the entire sample for the fully loaded condition and 0.1 percent shorter for the lightly loaded condition...it is concluded that the proposed adhesion utilization

requirements can be met...

This analysis makes the tacit assumption that if the five vehicles that did not meet the balance requirements were modified to do so, their average increase in stopping distance would be 0.17 percent as well. Our analysis of the trade-off suggests that a significantly higher difference would be the result of revising the cars in question to meet the balance requirement.

2) Analysis of the data in the NHTSA test report reveals that the distributions of performance to both FMVSS 105 and the proposed procedure can not be shown to be Gaussian (Normal). Thus the mathematics of Normal distributions should not be applied, or rather the attempts of the agency to use Normal distribution statistics to establish a "pooled estimate" may result in invalid conclusions.

3) The Method IV analysis is flawed because the variations are treated as if there was only one source, as if all the data came from the same population. The analysis treated the distribution as if it were Gaussian, but in fact each vehicle design is sufficiently different that each data point came from its own population with its own distribution characteristics. Each would create a "cluster" within the overall population. This type of distribution needs to be treated by "Analysis of Variance", a method that looks at the "between population" variances, as well as the "within population" variances. The sample size in this analysis is too small to characterize any of the several populations, so "within population" analysis cannot be performed, and "between population" data are limited to a single sample from each population.

4) The sample size was so small (19) that the various available tests for distribution shape are not reliably applicable. For this reason, we conducted an alternate analysis to see if the

pooled estimate from the small sample responded to a major difference in data. In order to develop a reliable pooled estimate, both the standard deviation and mean of the population must be accuratly predicted.

This can be demonstrated by the following analysis. When we applied the analysis NHTSA describes to the 19 car data set for FMVSS 105 second effectiveness 60 mph (96.5 km/h) and proposed 100 km/h (62.1 mph) full system effectiveness, we arrive at the following:

105 test average performance = 55.07
Harmonized test average performance = 59.00
105 test result standard deviation = 5.03
Harmonized test result standard deviation = 5.312
Pooled estimate equivalent = 66.504

If we change the lowest FMVSS 105 test data point, 143 feet, to equal 201 feet, (the other extreme of the observed range of this data), the numbers are as follows:

105 test average performance = 56.00
Harmonized test average performance = 59.00
105 test result standard deviation = 4.36
Harmonized test result standard deviation = 5.312
Pooled estimate equivalent = 66.488

Thus a change of one data point from one extreme of the observed range to the other resulted in an insignificant change in the pooled estimate (66.504 vs 66.488). This result appears to be due to compensatory changes in both the average and standard deviation. The 19 car sample may be large enough to provide a reliable estimate of the mean, but is not sufficient to reliably estimate the standard deviation. Thus the pooled estimate is inappropriate.

The agency discusses the adhesion utilization influence on meeting effectiveness requirements (stopping distances) on page V-16, making the following observation:

> The argument is that there is some degree of tradeoff between stability and stopping distance for some loading conditions. From a theoretical standpoint this argument has merit. However, the degree to which stopping capability is sacrificed has not been quantified, and the information available to the agency indicates that most vehicles which comply with the adhesion utilization requirements also comply with the effectiveness requirements of FMVSS 105.

Appendix 4 of these comments, Brake Balance Influence on Stopping Distance, provides some quantification of the increase in stopping distance attendant with a requirement for front bias, and additionally, with a vehicle test for front bias. Appendix 14, NHTSA Tests, takes a closer look at the ability of the vehicles in the NHTSA test to meet both the stopping distance and brake balance requirements. That analysis reveals that only two of the cars the agency tested appear to pass the FMVSS 135 proposals, and there is some question about those two.

On page V-19, the agency discusses Accident Reduction Potential of the adhesion utilization (front brake bias) concept, saying,

> The concept of adhesion utilization entails the brake system on a vehicle be so designed....that the vehicle can be stopped stabilly within a given

> distance. While there is no question that, directionally, a vehicle which meets the proposed adhesion utilization requirements should have greater accident avoidance potential than a vehicle which does not, the agency currently has no way of quantifying what this enhanced potential might be. (Emphasis added.)

GM strongly asserts that the underlined phrase in the text quoted above is false. GM also declares false the following statement in the Preamble of the Notice, on page 19747 of the Federal Register:

> However, if the rear wheels were to lock first, there would be a spin-out since those wheels would tend to lead.

The agency discusses fade heating cycles on pages V-20 through V-23. The agency describes testing done to reproduce temperatures in proposed fade tests that are equivalent to those observed in the FMVSS 105 fade sequence, which is claimed to be equivalent to a mountain descent. GM comments in Appendix 25, Fade Heating Cycles, compare the fade tests and actual mountain descents on the basis of energy input rather than the resultant brake temperature which is highly dependent upon individual vehicle characteristics. Based on the energy analysis, GM recommends the fade heating sequence of the R.88 proposal.

On pages V-29 through V-32, the agency discusses the relative stringency of the partial system requirements. The four methods of comparison discussed at length earlier in this Appendix are employed again by the agency to assess the partial system stopping distance requirements. The GM comments apply here as well.

NHTSA observes on page V-30:

> The direct conversion method yields an equivalent stopping distance of 149m, which is 4 percent less stringent than the 155m stopping distance of FMVSS No. 105. However, the direct comparison method (adjusting stopping distance only for the difference in initial speed) is deceiving in this instance, since the lower maximum allowable control force of the harmonized standard [500n (113 lb.) versus 150 lb.] appears to be the controlling factor.

(Apparently, the agency got its numbers reversed in the above quote. 155m is the FMVSS 135 proposal, not the FMVSS 105 requirement.) The Evaluation go on to say, on page V-32:

> Method II, which should account statistically for the additional differences between the two test procedures, yields a higher value of equivalent stringency (147m-173m for the worst case failed front at GVWR).
>
> The agency believes that this apparent increase in stringency is justified since the lower maximum control force was determined by research into the ergonomic capabilities of the driving population. Further, the stopping distance set at 40 percent of cold service brake deceleration is already rather lengthy, allowing in the neighborhood of 500 feet to stop the vehicle.

NHTSA has correctly determined that the proposed partial system stopping distances are more stringent than FMVSS 105, however the contention that such an increase in justified needs to be given more careful consideration in light of the facts involved. Appendix 19, Partial System Requirements, details the engineering analysis which concludes that the proposed requirement for partial systems would effectively preclude front-rear split systems, a design option that is still needed for some vehicles.

GM has not opposed the lower pedal force allowed under the new proposal because it is consistent with the goal of harmonization. However, the GM position consistently has been that reducing the pedal force requires an increase in allowable stopping distance. In this regard partial system requirements are affected to a greater degree than other requirements because pedal force limits are frequently encountered in this test phase.

Although NHTSA has mentioned (but not cited) ergonomic data on the capabilities of the driving population, no connection has been shown between any inability to apply the 150 pounds (667 N) allowed in FMVSS 105 (for partial systems or any other test requirement) and accident causation. The pedal force limit of the standard is simply a test condition, not a limit of the capability of the vehicle. Testing at 500 N (113 lbs.) does not preclude drivers in real world conditions from exceeding that force and obtaining shorter stopping distances as a result. GM contends that a need to increase the stringency of this requirement has not been demonstrated and that the agency's proposal for stringency above the level of the R.88 draft is not in the spirit of harmonization. GM does observe, however, that although the requirements proposed in R.88 represent a slight increase in stringency over FMVSS 105, they are within the capabilities of current passenger cars which are front biased, and are therefore acceptable.

The allegation that the stopping distance "is already rather lengthy" is an unsupported subjective judgement, which in addition has no connection to any established safety need.

The agency discusses spike stops on page V-33, saying:

> Spike stops are generally made from low speed with a rapid high force application of the brake pedal. They are meant to be a test of the integrity of the brake system, to be sure nothing breaks, deforms, or leaks after such a severe brake application.

GM contends (Appendix 28, Spike Stops and Final Effectiveness Tests) that spike stops are unnecessary considering that virtually all passenger cars today use disc brakes on the front, thereby eliminating the primary the SAE procedure on spike stops was designed to detect.

The agency discusses failed power assist requirements on pages V-35 through V-39 and once again uses the four methods of analysis described and commented upon above. GM's comments are once again pertinent. Additionally, GM is dismayed at the following comment on page V-37:

> Eleven of the 43 vehicles tested failed the proposed 155m performance criteria.
>
> In each of the eleven cases of vehicles failing to meet the proposed harmonized performance criteria the control forced input was at the maximum allowable value of 500n.

NHTSA's own tests establish that the proposed performance level is too stringent to be considered anything other than a deliberate upgrade of the brake requirements, once again without any field evidence to verify that such a change is needed.

The agency goes on to say:

> Compliance with this requirement will likely necessitate a redesign of either the mechanical or hydraulic portion (or both) of the braking system to achieve a higher before boost gain.

Appendix 19, Partial Systems Requirements describes the constraints on increasing booster gain, and these apply to "before boost" gain as well.

The agency discusses parking brake gradient hold on pages V-40 through V-46. At no point in this discussion does the agency explain the proposal to limit hand apply force to 320 N (72 pounds), a reduction not only from the FMVSS 105 allowable force, but also from the ECE R13 and R.88 proposal. Instead, the agency says, on page V-43:

> We have no human factors data for a parking control corresponding to that dealing with service braking, nor do we have any similar data dealing with hand parking brake controls.

NHTSA once again uses the four comparison methods previously discussed, presenting the results in Table V-6. GM does not consider this data any more valid than for the other requirements, but questions the agency decision to reduce the allowable hand apply force from the R.88 proposal of 400 N to 320 N, when the NHTSA analysis summarized in table V-6 lists the following estimates of equivalent stringency for uphill holding: 400, 300 to 340, 380, and 349 N.

The agency discusses costs in section VII. GM has not spent time analyzing costs since the standard, as currently drafted, is impracticable. Nonetheless, the GM comments on the specific requirements establish our disagreement with the assessment on page VII-3 that

> ...these variable costs...are expected to be minimal. Further, the number of affected vehicles is expected to be small.

RESPONSES TO NHTSA QUESTIONS

OBJECTIVE

The purpose of this section is to provide an easy reference for locating General Motors comments regarding the various issues in the proposed standard on which NHTSA has requested comments.

DISCUSSION

1. **Stringency of Proposed FMVSS 135 vs. FMVSS 105:** NHTSA requests comments on whether any methods other than the method used by NHTSA for the regulatory analysis should be considered for determining equivalent stringency.

GM Comments: General Motors comments regarding the stringency issue are contained in the general comments section and specific appendices on various requirements. Comments regarding the NHTSA regulatory evaluation and analysis of NHTSA research data are contained in Appendices 30 and 14.

2. **Adhesion Utilization Test Procedure:** NHTSA requests comments regarding the proposed single axle vehicle test procedure and on any others that should be considered.

GM comments: General motors believes that specifying a vehicle test for determining brake balance would forces the vehicle manufacturers to bias vehicle brake balance substantially away from the ideal, thus lengthening the stopping distances. Therefore, GM recommends that a calculation approach similar to the ECE Regulation 13 be used for this purpose. Detailed GM comments on this matter are contained in the general comments section and in Appendices 13, 4, and 17.

3. **Impact and Changes Necessary Due to the Adhesion Utilization requirements:** NHTSA requests comments on the number of vehicles affected by inclusion of the adhesion utilization requirement and the type of changes necessary to meet the proposed requirements.

GM comments: General Motors comments regarding the impact of an adhesion utilization test are contained in the general comments section and detailed comments are contained in the Appendices 4, 5, 12, and 17. As noted in response to question No. 2, a vehicle test for brake balance is inappropriate, and General Motors instead recommends a concept of nominal design with calculation approach. It is not timely to provide detailed comments regarding the type of changes necessary or the vehicles affected by the proposed requirement until NHTSA issues a supplementary notice. However, brief comments regarding use of anti-lock or variable proportioning valves to assure brake balance are contained in the general comments section and Appendices 23 and 24.

4. **Heating Sequence For Fade and Recovery Test:** NHTSA requests comments on specifying either one of the two proposed alternatives, one based on the SAE J-1247 procedure or the other based on a modified ECE procedure using 30 second interval instead of 45 seconds. If the second alternative specifying a 30 second interval is used, NHTSA requests comments on how vehicles that cannot accelerate to 120 km/h in 30 seconds should be tested.

GM comments: General Motors believes that the two proposed alternatives are overly abusive and not representative of the actual customer usage. GM recommends that either the fade heating cycle of R.88 be adopted or the proposed alternative No.2 be modified to extend the interval to 45 seconds. The detailed comments on this matter are contained in Appendix 25.

5. **Partial System Failure:** NHTSA recognizes that the proposed stopping distances for power assist failure represent an increase in stringency compared to the FMVSS 105 and the ECE draft due to the lower pedal effort and also due to the dependency of these proposed distances on the stopping distances specified for the full system performance requirements which are already more stringent than the current standard. NHTSA recognizes that 11 out of 43 cars tested by the agency failed the proposed requirement and redesigning of vehicle brake components will be necessary. Therefore, NHTSA requests comments on the power assist failure requirement. Further, NHTSA requests comments on the cost associated with meeting the requirement with an engine failed condition (accumulators or reservoirs).

GM comments: General Motors comments regarding impact of the reduced pedal effort and the stringent stopping distances on vehicles using the conventional front and rear split systems and the diagonal split brake systems are contained in Appendix No.24. Our comments regarding an engine failed requirements are contained in Appendix 21.

6. **Parking Brakes:** NHTSA recognizes that five vehicles out of 18 failed to meet the proposed stopping distance requirement in their tests due to the lower foot and hand applied efforts specified in the proposed standard. Therefore, NHTSA requests comments on the number of vehicles affected and the type of changes that may be necessary to meet the proposed requirements. Further, the proposed standard eliminates the FMVSS 105 optional procedure of using a 20 percent grade without the parking mechanism engaged and the moving barrier test. NHTSA requests comments on the appropriateness of eliminating this option.

GM comments: General Motors comments on the effect of lower apply efforts are contained in Appendix 19. The detailed comments regarding the proposed static and dynamic parking brake test procedures and the requirements are contained in Appendix 24.

7. **Equipment Integrity, Spike Stop and Final Effectiveness Tests:** Since the spike stops and the final effectiveness tests are not included in the ECE draft harmonized test, NHTSA requests comments on the desirability of their inclusion in the proposed standard.

GM comments: General Motors believes that the spike test and the final effectiveness tests are unnecessary. GM detailed comments regarding this matter are contained in Appendix 28.

8. **Equipment Safety:** NHTSA requests comments on appropriateness of permitting use of a fluid level sensor and activation of the brake warning light in situations of low fluid level instead of requiring a transparent reservoir to satisfy the requirement that the fluid level in a master cylinder reservoir be able to be checked without removing the cap.

GM comments: General Motors concurs with the NHTSA decision.

9. **Test Condition, Road Surface Specification:** NHTSA recognizes that the proposed method of using skid number for defining road surface is not generally used and therefore, requests comments on whether it should consider a method other than skid number for specifying test road surface. Further, NHTSA requests comments on whether it should consider using the ISO draft technical reports DTR #8349, Measurement of Road Surface Friction and DTR #8350, Specification for Construction of Road Test Surface, in developing a specification of road surface in terms of peak coefficient of friction.

GM comments: General Motors believes that the use of the slide coefficient of friction which is represented by a skid number for defining the test road surface is inappropriate and should not be used for a brake test. Instead, General Motors recommends that the method of defining the test road surface be based on using the tire-road peak coefficient of friction. However, General Motors does not recommend use the ISO draft procedures for this purpose. We believes that the ISO work on this matter is not complete or comprehensive and, therefore, the draft technical reports DTR 8349 and 8350, which are preliminary in nature, should not be used at this time. General Motors detailed comments on the tire-road traction dependent brake performance issues and the recommendations for establishing a method for defining a road surface for a brake test are contained in the general comments section and in Appendices 6, 7, and 11.

GM RECOMMENDED APPROACH

OBJECTIVE

The purpose of this Appendix is to identify a rulemaking approach that could lead to an international, harmonized brake standard.

CONCLUSIONS

1. The next step taken by the agency in developing FMVSS 135 should be to issue a supplemental notice of proposed rulemaking.

2. The supplemental notice should reflect international consensus on specific test provisions including the method of brake balance certification, the need for pre-burnished effectiveness requirements, the burnish schedule to be employed, the maximum and minimum apply force limits permitted, the final position on locked wheel stops or number of attempts to allow for each test requirement, and the fade heating cycle to be used.

3. Following the achievement of international consensus on these issues, the agency could then develop performance requirements consistent with the trade-offs and limits of current production brake systems.

RECOMMENDATIONS

GM offers the following recommendations:

1) The adoption of a brake balance certification procedure based on design calculation. This approach offers the highest

potential to achieve harmonization from both a brake balance and stopping distance perspective.

2) The adoption of maximum pedal force limits of 500 N (112 pounds) on the service and foot operated parking brakes and 400 N (90 pounds) on a hand operated parking brake.

3) Six attempts at each test requirement should be permitted, or locked wheel stops should be disregarded without penalty if only four attempts are permitted.

4) A fade heating cycle based on the R.88 procedure but run at constant deceleration rather than constant pedal force. Hot stop and recovery performance requirements based on baseline snubs run immediately prior to the fade heating cycle.

5) A 200 stop burnish schedule, to provide both brakes and tires adequate conditioning prior to performance assessment.

6) The elimination of pre-burnished effectiveness requirements.

DISCUSSION

The new information and analysis contained herein make it evident that significant changes in the performance requirements of FMVSS 135 are both desirable and necessary to achieve an international harmonized brake standard. This new vehicle and tire testing has shown that the physical laws governing brake and tire performance dictate that an increase in stopping distances is required if brake balance is to be front axle limited for all test conditions. The magnitude of the increase in stopping distance is impossible to quantify prior to the agency making several decisions regarding test procedures and certification methods.

As is demonstrated in Appendix 4, Brake Balance Influence on Stopping Distance,a final decision regarding the method of brake balance certification is necessary before any viable stopping distance requirements can be established. If a vehicle test is ultimately prescribed, a larger adjustment in stopping distance requirements will be necessary. Likewise, a vehicle test will also require substantial engineering testing before it is recognized internationally as a repeatable and valid test. International consensus on this issue is several years away. Beyond these points, a substantial body of objective test data related to variability will have to be gathered and available to interested parties for study prior to the adaptation of a vehicle test for brake balance.

A maximum pedal force limit of 500 N (112 pounds) on the service brake will probably be required to reach agreement with the European brake community which has operated with this limit for many years. In most cases, this would not be a burden on the U.S. manufacturers since power assisted brake systems have gained such wide acceptance within the domestic market. The notable exceptions to this general observation are in the test requirements associated with partial systems tests, no power tests, failed anti-lock, and failed variable proportioner tests. In each of these failed system tests, a maximum pedal force limit change from 150 pounds (667 N) in FMVSS 105 to 500 N (112 pounds) in FMVSS 135 dictates that a stopping distance correction be made. In the other effectiveness tests of FMVSS 135, GM has not asked for stopping distance adjustments to compensate for the lower pedal force limits since in our testing, vehicles are not normally pedal force limited.

It should be recognized that the reduced pedal force limits of FMVSS 135 will virtually preclude the use of manual brake systems in all passenger cars built for the U.S. market. To avoid this NHTSA should permit an FMVSS 105 equivalent 150 pound (667 N) pedal force limit for manual brake systems which would preserve the freedom of choice the customer currently is allowed.

As is shown in Appendix 15, the number of attempts allowed at each test requirement can have an impact on the stopping distance performance. Reducing the allowed number of attempts from 6 to 4 is an increase in stringency, and either an appropriate stopping distance correction must be made, or allowance must be made for locked wheel stops encountered during the testing to be aborted without being counted.

The fade heating cycle, and the related hot stop and recovery performance requirements need to be established serially, i.e., a fade heating cycle based on representative customer experience should be adopted first. Following identification of a specific fade heating cycle, reasonable hot stop and recovery performance requirements can be established. As is demonstrated in Appendix 25, Fade Heating Cycles, the FMVSS 105 first fade heating cycle, and both fade heating cycles of FMVSS 135 are far in excess of that measured in GVW descents of Pikes Peak. A modified R.88 fade heating cycle which uses a constant deceleration rather than a constant pedal force is more representative of customer needs for fade and recovery.

Once a fade heating cycle has been established and adopted, hot stop and recovery performance requirements can be determined on the basis of vehicle tests. To adopt such requirements in the absence of real vehicle data would be a mistake and contrary to the intent of harmonization.

Many of the proposed test requirements of FMVSS 135 are unnecessary and may serve as a serious impediment to harmonization. Among these are the pre-burnished effectiveness requirements, a lower hand operated parking brake pedal force limit, spike stops, and final effectiveness requirements. As is discussed in each of the appropriate response sections, these requirements are either redundant, or as presently proposed result in compromised brake system performance in the hands of the customer. These test requirements are not incorporated within either ECE R13 or draft proposal R.88. The European community has built and certified motor vehicles absent these requirements for many years without encountering a safety concern. To the extent the agency is able to eliminate these unnecessary, and in some cases counterproductive, requirements the cause of harmonization will be advanced.

The agency should carefully revisit the current requirements of draft proposal R.88. (GM has consistently referred to both the GRRF documents R.88 and R.94 as "R.88".) While still incomplete, this document is the result of more than four years of effort on the part of both regulatory and brake experts from around the world. As can be seen by reviewing the information contained in the GM response, the performance requirements of R.88 are considerably more realistic, relative to current production automobiles, than are the provisions of FMVSS 135. While the basis for adopting each of the requirements of R.88 may not have been supported by detailed data and analysis at the time, the extensive test data and analytical study contained within the GM response shows these requirements to be reasonable. Likewise, on a line by line comparison, the performance requirements of R.88 are generally more demanding than those of ECE R13 and thus represent a substantial increase in stringency. It is in our view highly unlikely that the European brake community would adopt performance requirements even more rigorous than those of R.88, absent either accident data or analysis supporting a safety need for such an increase in stringency.

General Motors believes that a continuation of the type of dialog that occurred at the special meeting of the GRRF in Dearborn in October of 1985 is essential to the development of an international harmonized brake standard. To that end, GM supports continued dialogue between industry and the agency, either to answer questions regarding various portions of this response or to address additional questions that may arise during the development of a supplemental notice of proposed rulemaking.

Importers & Distributors
of Ferodo Products

FERODO

Original Quality Inc.

OPTS Docket # 62036 Asbestos Ban
M/C E 92 File

SATISFACTION
GUARANTEED

ORIGINAL QUALITY, INC.
6653 Powers Road, Suite 23
JACKSONVILLE, FLORIDA 32217

1986 JUL 21 AM 9 51 AUG -8

62036
E92

Gentlemen:

Original Quality, Inc. is a very small business which imports friction materials from Ferodo Limited, which is located in England. Most of the friction materials are at the present an asbestos based product, however, the factory is presently experimenting with non-asbestos friction materials. Hopefully in the next few years there will be an asbestos free substitute for these asbestos based products.

Our company is one of the few manufacturers representatives located in the United States. We are an independent operation that sells brake pads, brake linings and clutch facings to foreign car repair shops, foreign car part houses, racing teams, road race car drivers, and also to the major road racing schools in the United States. Our volume of sales per year will be less than $100,000.

The majority of the products that we sell to our customers are sold for one primary reason - to stop a vehicle as soon as possible. Since most people that use our products are using these in high performance automobiles that may be traveling 100 to 200 mph, it is essential that they have excellent braking capabilities.

Ferodo, prides itself as being "THE CHOICE OF CHAMPIONS", because for twenty-three years Formula 1 World Champions all chose Ferodo Disc Pads. Likewise, the Ferodo product has become a very well known "brand name" among road racing enthusiasts.

The experts at the Ferodo production facility in England have informed us by letter that there is not a substitute at the present that is even remotely comparable to the quality of the product that is currently being marketed. They have estimated that it will take many years of research to develop a new asbestos free compound that will compare to the heat resistance of asbestos at operating temperatures between 350° and 1000° C.

Our immediate concern is twofold. First, it may take 5 to 10 years or even longer to produce an adequate substitute for the current racing disc brake pads,I would hope that certain exceptions might be granted on a limited basis to allow us to continue to provide high quality products to our customers during this interim period. The result of forcing all racing enthusiasts to use an inferior product also creates a safety hazard for the racing profession. Since the usage of these products is very minimal and used under strict operating conditions, we would hope that this proposed ruling would make an exception and allow our company to continue to provide high quality disc pads to our customers until a high quality asbestos free substitute becomes available.

Second, our other concern refers to section 763.148 (Issuance of Permits), Docket Control Number OPTS-62036 (Proposed Asbestos Ban Rule). Section (d) and (e) would be very difficult to monitor, because our company was owned by an individual that is now deceased and accurate records are not available for 1981,1982, and 1983. We would favor a ban of asbestos disc pads 10 years from now. This would allow researchers to develop new products for both the foreign car and racing markets. A total ban of all asbestos disc brake pads before 10 years will economically curtail our business operations, however we would support a system whereby we would actively promote and report the research progress of asbestos free disc pads on a regular basis, eg. semi-annually. We would actively support and we would promise to import all asbestos free products that become available and are recommended by the FERODO manufacturer for import to the United States.

We would hope that the drafters of this Proposed Asbestos Ban Rule would consider an equitable exemption system for those asbestos applications for which no substitutions can be developed. Examples might include lack of adequate research to produce new disc pads for all foreign cars or lack of economic means ro re-tool and re-die all disc brake pads for all foreign cars. Our company supports and would prefer to sell all asbestos free disc brake pads, especially for health reasons, however, our manufacturer, at the present has a very limited quantity of asbestos free disc pads for foreign cars. Since our market includes all foreign cars and most racing applications, our selling market is much broader than most of our competitors who specialize in a very few foreign cars or only in a few racing applications. Please consider adopting an equitable exemptions system for those applications for which no substitutions can be developed, or which may take 10 to 15 years to develop.

Thank you for allowing us to comment on this Proposed Asbestos Ban Rule, Docket Control Number OPTS-62036.

Sincerely,

Francis B Ballard

Francis B. Ballard
General Manager

cc. John Rigby

PEI Survey/
OPTS 62036 Asbestos Ban
Written Comm N(2)-015(1) File

62036
N2-15 (1)

1485

OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Contact: Erich Feierabend Date: 10/23/86

Title: Director of Manufacturing & Engineering

Company Name: Abex Corporation

Address: Papermill Road

P.O. Box 3250

City: Winchester State: Virginia Zip Code: 22601

Telephone: (703) 662-3871

Asbestos products manufactured: Brake linings

Approximate plant production capacity (for each product): N.A.

Manufacturing products containing asbestos at present (Yes/No)? Yes

EQUIPMENT DATA*
N/A

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

N.A.

3. Estimated time required to make conversion:

N.A.

4. Estimated cost of conversion:

N.A.

---

* Feierabend reported after receiving PEI's letter (see attached) that it is company policy not to participate in government surveys and general queries such as this one unless required to do so by law.

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

N.A.

6. Is equipment useable for another industry (Yes/No)? N.A. If Yes, please comment:

7. Can equipment be sold to foreign manufacturers (Yes/No)? N.A.

8. Has equipment already been sold (Yes/No)? N.A.

If Yes, please give name and address of purchaser

N.A.

9. Estimated cost of equipment teardown/cleanup:

N.A.

10. Would it be possible to arrange a future PEI visit (Yes/No)? N.A.

What is the procedure for obtaining permission to arrange a site visit?

Note: N/A = Not applicable
N.A. = Not available

EQUIPMENT DATA
ASBESTOS FRICTION MATERIALS
- N.A.* -

Equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight (tons)[b]
Mixer							
Preform compression molding machines							
Heated compression molding machines							
Combination slitter and cutter							
Arc-forming molding machine							
Curing oven							
Finishing equipment (drills, grinders, etc.)							
Other							
Other							
Other							
Other							
Other							

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

* It is company policy not to participate in government surveys or general queries unless required to do so by law.

PEI ASSOCIATES, INC.
(FORMERLY PEDCo ENVIRONMENTAL, INC.)

11499 CHESTER ROAD
CINCINNATI, OHIO 45246
(513) 782-4700
TELECOPIER (513) 782-4807

September 15, 1986

Mr. Erich Feierabend
Abex Corporation
Papermill Road
P.O. Box 3250
Winchester, Virginia 22601

Re: EPA Contract No. 68-02-4248
PEI PN 3687-23

Dear Mr. Feierabend:

Per our telephone conversation late this morning, this letter summarizes the details of our survey.

PEI Associates, Inc., is currently developing cost information for equipment used for manufacturing products containing asbestos. This work is being performed under the above referenced contract for the U.S. EPA Office of Toxic Substances. The EPA Task Manager is Christine M. Augustyniak (202) 382-3622.

As you may know, the Office of Toxic Substances has proposed a regulation to ban the use of asbestos in commerce over a 10-year period. Many comments were received on this proposal, several regarding the cost of converting existing equipment to other uses or the value of this equipment either in the used equipment market or as scrap. PEI, under this contract, is obtaining updated and revised equipment cost and related information to be used in the economic model. We are contacting asbestos product manufacturers (current as well as previous manufacturers) to obtain the best information possible. Used equipment dealers will also be contacted as part of the data-gathering effort. The attached list of questions shows the type of information we are requesting.

We appreciate any information you can give us and will consider any comments you may have regarding the convertability of equipment used to manufacture asbestos products. Thank you for your time. If you have any questions, please do not hesitate to call Fred Hall or me at (513) 782-4700.

Sincerely,

PEI ASSOCIATES, INC.

Michael T. Melia

MTM/sm

PEI Survey/
OPTS 62036 Asbestos Ban
Written Comm N(2)-15(2) File

1486

62036
N2-15(2)

OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Contact: Bob Baker Date: 9/18/86

Title: Plant Manager

Company Name: Adhesive Engineering Co.

Address: 1411 Industrial Road

City: San Carlos State: CA Zip Code: 94010

Telephone: (415) 592-7900

Asbestos products manufactured: Epoxy adhesives

Approximate plant production capacity (for each product): Product production confidential - (currently use 10,000 CBS asbestos/yr)

Manufacturing products containing asbestos at present (Yes/No)? No

By the end of this year all asbestos-containing products will be replaced.

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

   Yes - already in the process of converting product lines.

3. Estimated time required to make conversion:

   1 man-year of laboratory work needed to find alternative thickening agent
   No equipment changes required

4. Estimated cost of conversion:

   $20,000 (laboratory labor)

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

(No productivity loss) Product price actually decreased due to lowered
(No increase in labor) raw material costs.

6. Is equipment useable for another industry (Yes/No)? N/A If Yes, please comment:

Mixer could be used in paint industry if they wanted to sell it.

7. Can equipment be sold to foreign manufacturers (Yes/No)? N/A

8. Has equipment already been sold (Yes/No)? N/A

If Yes, please give name and address of purchaser

9. Estimated cost of equipment teardown/cleanup:

$0 - No equipment changes required

10. Would it be possible to arrange a future PEI visit (Yes/No)? Yes

What is the procedure for obtaining permission to arrange a site visit?

Bob Baker

Note: N/A = Not applicable
N.A. = Not available

EQUIPMENT DATA
ASBESTOS SEALANTS/COATING

Primary equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight (lb)[b]
Dispersion mixer - 500-gal tank, 30-HP mixer[c]	1	20	10	50-70,000	5,000		2,000

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

[c] Fillers, pigments, etc. are added manually (forklifts - drum bags by hand) into dispersion tank containing the liquid epoxy material, mixed together and sent to packaging area. Epoxy resin is stored in large bulk storage tanks.

PEI Survey/
OPTS 62036 Asbestos Ban
Written Comm N(2) -15(3) File

1487

62036
N2 -15 (3)

OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Contact: Craig Larson Date: 10/23/86

Title: Environmental Technologist

Company Name: Allied Automotive

Address: Cohoes Road & Tibbits Avenue

City: Green Island State: New York Zip Code: 12183

Telephone: (518) 273-6550

Asbestos products manufactured: Asbestos drum brake linings; disc brake pads, brake blocks, clutch facings.

Approximate plant production capacity (for each product): N.A.

Manufacturing products containing asbestos at present (Yes/No)? N.A.

EQUIPMENT DATA*

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

   N.A.

3. Estimated time required to make conversion:

   N.A.

4. Estimated cost of conversion:

   N.A.

* Larson received the letter from PEI explaining the purpose of this study (see attached), but was not permitted to respond by the company. A letter from EPA to Allied Automotive reporting that PEI was authorized to gather the data would be required before the company would "consider" supplying the data.

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

N.A.

6. Is equipment useable for another industry (Yes/No)? N.A. If Yes, please comment:

7. Can equipment be sold to foreign manufacturers (Yes/No)? N.A.

8. Has equipment already been sold (Yes/No)? N.A.

If Yes, please give name and address of purchaser

N.A.

9. Estimated cost of equipment teardown/cleanup:

N.A.

10. Would it be possible to arrange a future PEI visit (Yes/No)? N.A.

What is the procedure for obtaining permission to arrange a site visit?

Note: N/A = Not applicable
N.A. = Not available

EQUIPMENT DATA
ASBESTOS FRICTION MATERIALS
- N.A.* -

Equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight (tons)[b]
Mixer							
Preform compression molding machines							
Heated compression molding machines							
Combination slitter and cutter							
Arc-forming molding machine							
Curing oven							
Finishing equipment (drills, grinders, etc.)							
Other							
Other							
Other							
Other							
Other							

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

* Company would not consider sypplying data without specific letter from EPA authorizing PEI to collect the information. There is no guarantee that the company would supply the information even with the EPA letter.

PEI Survey/
OPTS 62036 Asbestos Ban
Written Comm N(2) 15(4) File

EPA/OPTS
TSCA PUBLIC FILES

1986 NOV -5 AM 9:16

AMERICAN BILTRITE INC

1488

62036
N_2-15(4)

October 9, 1986

Mr. Christopher J. Meyer
PEI ASSOCIATES, INC.
Chester Towers
Cincinnati, Ohio 45246

Re: EPA Contract No. 68-02-4248
PEI PN 3687-23

Dear Mr. Meyer:

Our company discontinued the use of asbestos fiber in our manufacturing process as of last year and since we no longer utilize asbestos, it is our company policy not to divulge the type of information you requested in your letter of October 1, 1986. We have in the past complied with the appropriate regulations on asbestos reporting issued July 30, 1982.

Sincerely,

AMERICAN BILTRITE, INC.

Merrill M. Smith

Merrill M. Smith
Vice President of Technology

MMS:rv

AMTICO

AMTICO FLOORING DIVISION
3131 Princeton Pike
P.O. Box 6146 08648-0146
Lawrenceville, NJ 08648-2207
609-896-3000 Telex: 843-440

PEI Survey/
OPTS 62036 Asbestos Ban
Written Comm N(2)-15(5) File

CYANAMID

1502

62036
N_2-15(5)

American Cyanamid Company
Polymer Products Division
Engineered Materials Department
Bloomingdale Plant
Havre de Grace, MD 21078
(301) 939-1910

October 13, 1986

1986 NOV -5 AM 9:18
EPA/OTS
TSCA PUBLIC FILES

Mr. Ronald S. McKibben
11499 Chester Road
Cincinnati, OH 45246

Dear Mr. McKibben:

This letter is in response to PEI Associates' request for information concerning asbestos usage and processing at American Cyanamid's Havre de Grace, Maryland facility.

In the absence of an official request for information from the U.S. EPA, the American Cyanamid Company is concerned about releasing confidential business information to an EPA consultant. Therefore, the American Cyanamid Company declines to respond to this survey at this time.

Very truly yours,

Dennis G. Averill

Dennis G. Averill
Mgr Safety & Environmental

/ljp

MANUFACTURE ADHESIVES
FOR AEROSPACE
INDUSTRY — AIRCRAFT/
SPACE VEHICLES —
STILL USE ASBESTOS

PEI Survey/
OPTS 62036 Asbestos Ban
Written Comm N(2)-15(6) File

1489

62036
N_2-15(6)

OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Contact: Mr. Donald Davis Date: 9/18/86

Title: Production Manager

Company Name: American Tar Company

Address: 1700 N. Northlake Way

City: Seattle State: WA Zip Code: 98103

Telephone: (206) 632-0828

Asbestos products manufactured: Cold application roof coatings

Approximate plant production capacity (for each product): 800,000 gal/yr

(make 1- and 5-gallon drum, and sell bulk truckloads)

Manufacturing products containing asbestos at present (Yes/No)? Yes

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

   Yes - ribbon mixer only

3. Estimated time required to make conversion:

   2 man-weeks - remove fluffing machines and vacuum system and install new equipment - ribbon mixer would be left in place and reused.

4. Estimated cost of conversion:

   $3000 to $4000 (labor)
   Capital - $5000 (additional equipment) - install new conveying/hopper equipment

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

Productivity would be decreased by 10 percent - this is because more raw materials would have to be added* - Product price would also increase by 15 percent.

6. Is equipment useable for another industry (Yes/No)? No If Yes, please comment:

Ribbon mixer could possibly be sold and used in another industry.

7. Can equipment be sold to foreign manufacturers (Yes/No)? Yes

8. Has equipment already been sold (Yes/No)? No

If Yes, please give name and address of purchaser

____

____

____

____

9. Estimated cost of equipment teardown/cleanup:

$2000 labor cost

10. Would it be possible to arrange a future PEI visit (Yes/No)? Yes

What is the procedure for obtaining permission to arrange a site visit?

Call Donald Davis, the Production Manager

Note: N/A = Not applicable
N.A. = Not available

* Six materials versus three would have to be added to get same consistency in product.

EQUIPMENT DATA
ASBESTOS ADHESIVES/SEALANTS

Primary equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight (lb)[b]
Fluffing machine	3	5	10	3,000 ea.	0	?	800 ea.
Ribbon mixer	4	15	15	20,000 ea.	5,000	?	2,500 ea.
Vacuum system[c]	1	10	10	15,000 ea.	0	?	2,000 ea.

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

[c] Consists of ductwork (80 ft), exhaust fan, cyclone, shaker, and HEPA exhaust filter.

PEI Survey/
OPTS 62036 Asbestos Ban
Written Comm N(2)-15(7) File

1490

OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

62036
N_2-15(7)

Contact: JACK B. Headley

Date: 1986 NOV 9 5 30 - 86

Title: Chief Environmental Chemist

Company Name: Armstrong World Industries, Inc

Address: Liberty + Charlotte Sts.

City: Lancaster State: Pa. Zip Code: 17604

Telephone: 717-396-2031

(Past or Present) Asbestos products manufactured: Tile, Adhesives

Approximate plant production capacity (for each product): Varied - confidential

Manufacturing products containing asbestos at present (Yes/No)? NO

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)? yes

3. Estimated time required to make conversion: has been done

4. Estimated cost of conversion: - None

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

No effect.

6. Is equipment useable for another industry (Yes/No)? NO If Yes, please comment: we have converted to non asbestos products.

7. Can equipment be sold to foreign manufacturers (Yes/No)? yes

8. Has equipment already been sold (Yes/No)? NO

   If Yes, please give name and address of purchaser

   ____

   ____

   ____

   ____

9. Estimated cost of equipment teardown/cleanup:

   N/A

10. Would it be possible to arrange a future PEI visit (Yes/No)? NO

    What is the procedure for obtaining permission to arrange a site visit?

Note: N/A = Not applicable
N.A. = Not available

N/A - we have converted to non asbestos products - 1980-81

EQUIPMENT DATA
VINYL-ASBESTOS FLOOR TILE

Equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight (tons)[b]
Bulk storage silos, tank							
Material transfer equipment (air conveyor or pump)							
Automatic weighing and charging equipment							
Ribbon blenders							
Vibrating conveyors							
Fluxing equipment							
Mills							
Strainer							
Calendar							
Product stripping (from calendar)							
Pattern impression/impregnation equipment							
Product cooling (rolls or bath)							
Thickness gauge							
Trimming and cutting							
Packaging							
Heating units (for calendar rolls, fluxing and blending)							
Cooling system							
Other							
Other							
Other							
Other							
Other							

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

PEI Survey/
OPTS 62036 Asbestos Ban
Written Comm N(2)-15(8) File

62036
N_2-15(8)

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OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Contact: Mitchell Comins   Date: 10/14/86

Title: Vice President

Company Name: Auto Friction Corp

Address: 3 Shepard Street

City: Lawrence   State: MA   Zip Code: 01842

Telephone: (617) 686-3926

Asbestos products manufactured: Drum brake linings; disc brake pads (light & medium); brake blocks mixed or repackaged asbestos fiber.

Approximate plant production capacity (for each product): N.A.

Manufacturing products containing asbestos at present (Yes/No)? Yes/No (block & fiber).

EQUIPMENT DATA*

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

   Same equipment used.

3. Estimated time required to make conversion:

   Required continual change over a 2-5 year period.

4. Estimated cost of conversion:

   No cost figures were available but Comins reported that R&D costs were the most prominent.

---

* Mr. Comins was very impatient when discovering that this was a government survey. He was polite but cut off the telephone interview after only a few minutes indicating that his time was short and this was a survey about which he had no interest.

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

N.A.

6. Is equipment useable for another industry (Yes/No)? N.A. If Yes, please comment:

7. Can equipment be sold to foreign manufacturers (Yes/No)? N.A.

8. Has equipment already been sold (Yes/No)? No

If Yes, please give name and address of purchaser

N/A

9. Estimated cost of equipment teardown/cleanup:

N.A.

10. Would it be possible to arrange a future PEI visit (Yes/No)? No

What is the procedure for obtaining permission to arrange a site visit?

Note: N/A = Not applicable
N.A. = Not available

EQUIPMENT DATA
ASBESTOS FRICTION MATERIALS
- N.A.* -

Equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight (tons)[b]
Mixer							
Preform compression molding machines							
Heated compression molding machines							
Combination slitter and cutter							
Arc-forming molding machine							
Curing oven							
Finishing equipment (drills, grinders, etc.)							
Other ______							
Other ______							
Other ______							
Other ______							
Other ______							

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

* No equipment data available for this facility.

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PEI Survey/
OPTS 62036 Asbestos Ban
Written Comm N(2)-15(9) File

62036
N2-15(9)

OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Contact: Mr. Donald Buckman

Date: 9/23/86

Title: Manufacturing Manager

Company Name: Atlas Minerals & Chemicals, Inc.

Address: Farmington Road

City: Mertztown State: PA Zip Code: 19539

Telephone: (215) 682-7171

Asbestos products manufactured: Industrial asbestos mortar (brick cement)

Approximate plant production capacity (for each product): 1,560,000 lb/yr*

- product contains 1% asbestos.

Manufacturing products containing asbestos at present (Yes/No)? Yes**

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

   Yes - 57 other products are currently being made with same equipment - the only piece of equipment not used to make the asbestos product is the conveyor which feeds the ribbon mixer. Asbestos is added directly when making asbestos products.

3. Estimated time required to make conversion:

   None - Finding new raw material to replace the asbestos is the only problem.

EPA/OTS
TSCA PUBLIC FILES
1986 NOV -5 AM 9:17

4. Estimated cost of conversion:

   None except for time spent finding substitute material.

* Three batches/day, 2000 lb/batch, 5 days/week, 52 weeks/yr.

** Currently manufacture 60 different products - three contain asbestos - all 60 products are manufactured with same equipment.

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

Did not know - have yet to find substitute material.

6. Is equipment useable for another industry (Yes/No)? Yes If Yes, please comment:

Any dry powder mixing industry.

7. Can equipment be sold to foreign manufacturers (Yes/No)? No

8. Has equipment already been sold (Yes/No)? N/A

If Yes, please give name and address of purchaser

____

____

____

____

9. Estimated cost of equipment teardown/cleanup:

(8-h day) 2 men/day ($14/h including overhead)
$225 to tear down/clean up ribbon mixer

10. Would it be possible to arrange a future PEI visit (Yes/No)? Yes

What is the procedure for obtaining permission to arrange a site visit?

Mr. Donald Buckman

Note: N/A = Not applicable
N.A. = Not available

EQUIPMENT DATA

Primary equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight (tons)[b]
Ribbon mixer[c]	1	15	20	15,000	1500	NA[d]	1 ton
Dust collector	1	15	20	3,000	Included above	NA	Minimal weight

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

[c] Product is produced by adding asbestos manually directly into ribbon mixer feed hopper - product is then poured out of mixer into bags and bags are sewn closed.

[d] NA = Not available.

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PEI Survey/
OPTS 62036 Asbestos Ban
Written Comm N(2)-15(10) File

62036
N2-15(10)

OTS SURVEY FORM
EPA/OTS ASBESTOS PRODUCTS MANUFACTURERS
TSCA PUBLIC FILES

Contact: Bill Outcalt 9 15

Date: 9/18/86

Title: Plant Manager

Company Name: Aztec Industries

Address: 14 South Common St.

City: North Brookfield State: MA Zip Code: 01535

Telephone: (219) 267-3171

Asbestos products manufactured: Clutch and brake parts, friction materials - for use in oil fields

Approximate plant production capacity (for each product): 1985 - Used 60 tons asbestos - produced approximately 120 tons of products

Manufacturing products containing asbestos at present (Yes/No)? Yes.

Making asbestos and nonasbestos products
25 to 30 percent nonasbestos now; by end of year all nonasbestos products are anticipated.

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

   Can be done readily - Molding equipment is the one thing being converted. Material flows differently - if it contains nonasbestos materials, it "splashes around". Aztec is currently testing a new nonasbestos material which acts like asbestos and would not require conversion of the molding equipment.

3. Estimated time required to make conversion:

   1 to 3 weeks/mold to make their own mold.

   New nonasbestos material may not require conversion of molds.

4. Estimated cost of conversion:

   $5,000 to $10,000 new mold
   Changed 12 to 15 molds over the last year

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

Less tool life (and thus less productivity) occurs with nonasbestos products. New nonasbestos material may be less hard on tools. Converted equipment operating rate is essentially same as new equipment designed for asbestos substitute products.

6. Is equipment useable for another industry (Yes/No)? No If Yes, please comment:

7. Can equipment be sold to foreign manufacturers (Yes/No)? N/A

8. Has equipment already been sold (Yes/No)? N/A

If Yes, please give name and address of purchaser

9. Estimated cost of equipment teardown/cleanup: N/A

10. Would it be possible to arrange a future PEI visit (Yes/No)? Yes

What is the procedure for obtaining permission to arrange a site visit?

Frank Gatke, Jr. - Owner or go through Bill Outcalt

Note: N/A = Not applicable
N.A. = Not available

EQUIPMENT DATA
ASBESTOS FRICTION MATERIALS

Primary equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value each ($)	Scrap value ($)	Equipment weight (tons)[b]
Mixer[c]	2	40+	10	d	~~20,000~~ 2000	50	N.A.
		20	10		~~40,000~~ 4000	50	
Preform compression molding machines	3	40+	25-30	20,000 new	5,000	200	N.A.
Heated compression molding machines	75	40+	25-30	e	f	200	g
Combination slitter and cutter	0						
Arc-forming molding machine[h]	1000	4-40	5-10 (older)	1,000-10,000	0	N.A.	25 lb-1 ton
Curing oven[i]	0						
Finishing equipment (drills, grinders, etc.)	100	5-40	10 (older)	j	500	100	1-3
Other Boiler	1	4	20+	100,000	10,000	0	k
Other Dust collector - baghouse	3 large, 8 small	15-25	3-10	250,000 for all	0	0	N/A
Other Dust collector - wet collector	1	25	1	30,000	0	0	N/A

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

[c] Anticipate purchasing a used mixer next year.

[d] Cost for used mixer ranges from $10,000 to $15,000; for new mixer ranges from $35,000 to $40,000.

[e] Cost for a new small machine is $10,000; for a large new machine (52-in. ram) is $125,000.

[f] Resale value of a small machine (which most are) is $5,000; value of a large machine is $20,000.

[g] Weight of small machine is approximately 1,000 lb; weight of a large machine is 60 tons.

[h] Arc-forming molding machines are sized from 12 to 48 in., with thicknesses of ¼ to 3 in.

[i] Not used in conjunction with asbestos products. Asbestos products cured by heated presses which receive steam from the boiler.

[j] Approximately $1,000 for drills, $12,000 for lathes, and $35,000 to $40,000 for grinders.

[k] Dimensions 25 ft x 15 ft x 20 ft.

PEI Survey/
OPTS 62036 Asbestos Ban
Written Comm N(2)-15(11) File

1494

62036
N_2-15(11)

OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Contact: Kenneth Sears Date: 9/22/86

Title: Plant Manager

Company Name: Bacon Industries

Address: 16731 Hale Avenue

City: Irvine State: CA Zip Code: 92714

Telephone: (714) 863-1499

Asbestos products manufactured: Adhesives

Approximate plant production capacity (for each product): 120 lb of asbestos-containing materials in 1985 - less than 1% of total product capacity.

Manufacturing products containing asbestos at present (Yes/No)? No

Working off pre-made asbestos-containing concentrates. Hope to discontinue all asbestos products by next month.

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

   Yes - presently is being used in such a fashion.

3. Estimated time required to make conversion: None

4. Estimated cost of conversion: Laboratory costs only - still researching.

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

   No change in operating rate occurred. No difference between converted and specifically designed equipment.

6. Is equipment useable for another industry (Yes/No)? Yes If Yes, please comment:

   Paint, varnish, anything mixing liquids

7. Can equipment be sold to foreign manufacturers (Yes/No)? N/A

8. Has equipment already been sold (Yes/No)? N/A

   If Yes, please give name and address of purchaser

   ____

   ____

   ____

   ____

9. Estimated cost of equipment teardown/cleanup: None

10. Would it be possible to arrange a future PEI visit (Yes/No)? Yes

    What is the procedure for obtaining permission to arrange a site visit?

    Ken Sears

Note: N/A = Not applicable
N.A. = Not available

EQUIPMENT DATA
ASBESTOS ADHESIVES/SEALANTS/COATING

Primary equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight[b] (lb)
Myer's Mixer (high shear)	2	7	10	N.A.	N/A	0	200-300
Baghouse	1	N.A.	10	N.A.	N.A.	N.A.	N.A.

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

1523

PEI Survey/
OPTS 62036 Asbestos Ban
Written Comm N(2)-15(12) File

62036
N2-15(12)

Specialty Paperboard Division

Latex Fiber Products
Beaver Falls, New York 13305
315/346-1111
Telex: 937-396

Boise Cascade

October 3, 1986

Mr. Chris Meyer
PEI Associates, Inc.
11499 Chester Road
Cincinnati, Ohio 45246

RE: EPA Contract No. 68-02-4248
PEI PN 3687-23

Dear Mr. Meyer:

Enclosed please find the completed OTS Survey Form - Asbestos Products Manufacturers that you requested.

If you have any questions, please contact me.

Thank you.

Sincerely,

Jonathan Mayo

Jonathan E. Mayo
Sr. Project Engineer

JEM/sb

Enclosures

1523a

62036
N_2-15(12)(1)

PEI ASSOCIATES, INC.
(FORMERLY PEDCo ENVIRONMENTAL, INC.)

11499 CHESTER ROAD
CINCINNATI, OHIO 45246
(513) 782-4700
TELECOPIER (513) 782-4807

September 18, 1986

Mr. Jonathan Mayo
Senior Project Engineer
Boise Cascade Corporation
Main Street
Beaver Falls, New York 13305

Re: EPA Contract No. 68-02-4248
PEI PN 3687-23

Dear Mr. Mayo:

Per our telephone conversation, this letter summarizes the details of our survey.

PEI Associates, Inc., is currently developing cost information for equipment used for manufacturing products containing asbestos. This work is being performed under the above referenced contract for the U.S. EPA Office of Toxic Substances. The EPA Task Manager is Christine M. Augustyniak (202) 382-3622.

As you may know, the Office of Toxic Substances has proposed a regulation to ban the use of asbestos in commerce over a 10-year period. Many comments were received on this proposal, several regarding the cost of converting existing equipment to other uses or the value of this equipment either in the used equipment market or as scrap. PEI, under this contract, is obtaining updated and revised equipment cost and related information to be used in the economic model. We are contacting asbestos product manufacturers (current as well as previous manufacturers) to obtain the best information possible. Used equipment dealers will also be contacted as part of the data-gathering effort. The attached list of questions shows the type of information we are requesting.

We appreciate any information you can give us and will consider any comments you may have regarding the convertability of equipment used to manufacture asbestos products. Due to the time constraints of this project, we would like to have this information returned as soon as possible, preferably by Friday, September 26. Thank you for your time. If you have any questions, please do not hesitate to call Fred Hall or me at (513) 782-4700.

Sincerely,

PEI ASSOCIATES, INC.

Chris Meyer

Chris Meyer

CM/sm

15236

62036
N_2-15(12)2

OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Contact: Jonathan Mayo Date: 9/22/86

Title: Senior Project Engineer

Company Name: Boise Cascade Corporation

Address: Main Street

City: Beaver Falls State: N.Y. Zip Code: 13305

Telephone: (315) 346-1111

Asbestos products manufactured: Gasket Sheet

Approximate plant production capacity (for each product): 28 Tons/Day

Manufacturing products containing asbestos at present (Yes/No)? Yes

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

   Yes.

3. Estimated time required to make conversion:

   3 years.

4. Estimated cost of conversion:

   $7.2 Million; This cost is based on a "best guess" of what equipment would be necessary. Substitute materials have not yet been successfully developed for many product areas and therefore equipment requirements are not well defined.

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

Due to the fact that substitute products have not been successfully developed for all product areas, we don't know what "equipment specifically designed..." would consist of.

6. Is equipment useable for another industry (Yes/No)? Yes If Yes, please comment:

This equipment however, may not be profitable if used in other market areas.

7. Can equipment be sold to foreign manufacturers (Yes/No)? No

8. Has equipment already been sold (Yes/No)? No

If Yes, please give name and address of purchaser

9. Estimated cost of equipment teardown/cleanup:

$200,000.00

10. Would it be possible to arrange a future PEI visit (Yes/No)? No

What is the procedure for obtaining permission to arrange a site visit?

Note: N/A = Not applicable
N.A. = Not available

EQUIPMENT DATA
ASBESTOS GASKETS/PACKINGS

Primary equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight,[b] (tons)
Cylinder Paper Machine	1	70	?	$12 MM	$50 M	?	100 T

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

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OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Contact: Steven Simon   Date: 9/23/86

Title: Acting Executive President

Company Name: Brassbestos Mfg. Corporation

Address: 45 East Fifth Street

City: Paterson   State: New Jersey   Zip Code: 07524

Telephone: (201) 278-6655

Asbestos products manufactured: Brake pads and drum linings - some brake pads produced here were made with asbestos substitutes.

Approximate plant production capacity (for each product): 1×10^6 pieces/month for pads & 800K pieces/month for drum linings when doing well*.

Manufacturing products containing asbestos at present (Yes/No)? No

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

   The equipment used at this plant was custom designed by the company for the manufacture of the products listed. Equipment use is very specialized and conversion is not easy.

3. Estimated time required to make conversion:

   Depends upon the resources of the company. With a good amount of available capital the conversion could be completed in a year. More typically the conversion would take 4 to 5 years.

4. Estimated cost of conversion:

   N.A.

* Company has gone out of business. At one time had 17% of the market. Slipped to 1% just prior to plant closing several months ago.

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

   The flow of materials is significantly reduced when changing to asbestos. The process becomes more complicated (e.g., hang ups at scales) using the asbestos substitutes. This could be compensated for through engineering.

6. Is equipment useable for another industry (Yes/No)? No If Yes, please comment:

7. Can equipment be sold to foreign manufacturers (Yes/No)? Yes

   The return is very low. For a $25,000 item a South American Company may purchase for $3-4000.

8. Has equipment already been sold (Yes/No)? Yes

   If Yes, please give name and address of purchaser

   Friction Division Products, Inc.

9. Estimated cost of equipment teardown*/cleanup:

   There is a tremendous environmental problem for the manufacturer in New Jersey as a result of RCRA regulations for commercial property transfer. A building must meet clean up standards prior to deed transfer. Since the plant closed the company has paid $30,000/yr for insurance and $25,000/yr in taxes plus other costs. The plant has been closed for a year and $200,000 has been spent so far waiting for an EPA inspection. An additional $100-600,000 is projected to be spent before approval to sell property is issued.

10. Would it be possible to arrange a future PEI visit (Yes/No)? Yes, (but all equipment has been removed)

    What is the procedure for obtaining permission to arrange a site visit?

Note: N/A = Not applicable
N.A. = Not available

* There was no cost reported for teardown because it was underwritten by the equipment purchaser. The equipment was sold for $360,000 of which $56,000 was attributed to teardown.

EQUIPMENT DATA
ASBESTOS FRICTION MATERIALS

Equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight (tons)[b]
Mixer	11[c]					N.A.	
Preform compression molding machines	12[d]					N.A.	
Heated compression molding machines	2					N.A.	
Combination slitter and cutter	5					N.A.	
Arc-forming molding machine	2000					N.A.	
Curing oven	5					N.A.	
Finishing equipment (drills)	21[e]					N.A.	
Finishing equipment (grinders)	4					N.A.	
Other							
Other							
Other							
Other							
Other							
Average/Total:		20-25 (drum equip.) 2-15 (pad equip.)		$2mm	$304K[g]		(1.5mm lbs)

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

[c] 4 for drums and 7 for manufacture of pads.

[d] 4 for drums and 8 for pads.

[e] 9 for drums; 12 for pads.

[f] Indefinite for drums; 10 years for pad equipment.

[g] Actual selling price.

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OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS/MINING

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Contact: Joey Toney

Date: October 8, 1986

Title: Director of Environmental Affairs

Company Name: Calaveras Asbestos, Ltd.

Address: P.O. Box 127

City: Copperopolis State: CA Zip Code: 95228

Telephone: 209/785-2201

Asbestos products manufactured: Chrysotile Asbestos Mine and Mill

Approximate plant production capacity (for each product):

34,000 tons Chrysotile Asbestos per year

Manufacturing products at present (Yes/No)? Mining and Milling at present

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for other use (e.g., same product different material)?

   No other use for milling equipment.

   Some rock crushing and mining equipment can be sold as used mining/construction equipment.

3. Estimated time required to make conversion:

   N/A

4. Estimated cost of conversion:

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5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

N/A

6. Is equipment useable for another industry (Yes/No)? some If Yes, please comment:

Milling equipmenet has no other use. Some rock crushing and mine equipment can be sold as used mining/construction equipment.

7. Can equipment be sold to foreign manufacturers (Yes/No)? No

8. Has equipment already been sold (Yes/No)? No.

If Yes, please give name and address of purchaser

____

____

____

____

9. Estimated cost of equipment teardown/cleanup:

Tear down - $850,000

Cleanup - Costs would far exceed any resale or scrap value.

10. Would it be possible to arrange a future PEI visit (Yes/No)? Yes

What is the procedure for obtaining permission to arrange a site visit?

Phone contact person.

Note: N/A = Not applicable
N.A. = Not available

EQUIPMENT DATA

Primary equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight (tons)[b]
Mine Equipment	N/A	6-10	5-8	6,000,000	600,000	N/A	1,090
Rock Crushing Equipment	N/A	20	10	2,000,000	80,000	*40,500	675
Dryer Equipment	N/A	21	8	1,200,000	40,000	*13,000	215
Mill Equipment	N/A	27	8	5,600,000	N/A	*74,000	1,230
Tailings Equipment	N/A	20	8	400,000	N/A	* 8,500	135
Baghouses	N/A	17-27	6	2,600,000	N/A	*27,000	450
Utilities Equipment	N/A	27	10	1,200,000	N/A	*20,000	100
Buildings	N/A	8-27	30	6,000,000	12,000	*99,000	2,500

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

*Cleanup costs alone would far exceed any possible scrap or resale value. If all costs related to forced shutdown were considered, resale and scrap value would be exceeded by several million dollars.

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62036
N_2-15(15)

capco

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CAPCO PIPE COMPANY, INC. — A Subsidiary of ASARCO Incorporated
1400 Twentieth Street, South • P. O. Box 55379 / Birmingham, Alabama 35255 • Phone 205 • 933-7281

WARREN T. WHITLEY
President

RECEIVED

PEI ASSOCIATES, INC.

October 21, 1986

PEI Associates, Inc.
11499 Chester Rd.
Cincinnati, Ohio 45246

Attention: Yatendra M. Shah, P.E.

RE: EPA Contract No. 68-02-4248
PEI PN 3687-23

Gentlemen:

In accordance with your letter of September 22, 1986 addressed to our Mr. Sam Leyshock, please find enclosed CAPCO Pipe Company's completed OTS Survey Form (Asbestos Products Manufacturers).

Very truly yours,

CAPCO PIPE COMPANY, INC.

Warren T. Whitley
President

Enclosure

dc

Quality Piping Materials

1497a

OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Contact: W. T. WHITLEY Date: 10-8-86

Title: PRESIDENT

Company Name: CAPCO PIPE COMPANY

Address: 1400 So. 20th STREET

City: BIRMINGHAM State: AL Zip Code: 35205

Telephone: 205-933-7281

Asbestos products manufactured: WATER AND SEWER PIPE

Approximate plant production capacity (for each product):

TOTAL 50,000 TONS

Manufacturing products containing asbestos at present (Yes/No)? YES

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

   NO KNOWN SUBSTITUTES AVAILABLE

3. Estimated time required to make conversion:

   —

4. Estimated cost of conversion:

   —

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

—

6. Is equipment useable for another industry (Yes/No)? No If Yes, please comment:

7. Can equipment be sold to foreign manufacturers (Yes/No)? No

8. Has equipment already been sold (Yes/No)? No

If Yes, please give name and address of purchaser

____

____

____

____

9. Estimated cost of equipment teardown/cleanup:

$3-4 MILLION

10. Would it be possible to arrange a future PEI visit (Yes/No)? YES

What is the procedure for obtaining permission to arrange a site visit?

REQUEST IN WRITING TO BIRMINGHAM ADDRESS TO OFFICE OF PRESIDENT

____

Note: N/A = Not applicable
N.A. = Not available

EQUIPMENT DATA
ASBESTOS-CEMENT PIPE EQUIPMENT

Equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight (tons)[b]
Bag opening	0						
Screw conveyors							
Fiber opener							
Blender							
Mixer							
Slurry conveyor							
Pipe machine	1						
Spare mandrels							
Precure ovens	2						
Pipe conveyors							
Final curing ovens	5						
Hydrostatic testing machine	2						
Pipe cutting lines	3						
Pipe lathes/milling machines							
Pipe coating line	1						
Overhead cranes/pipe conveyors	4						
Pallet making shop	6						
Shipping equipment							
Other							
Other							
Other							
Other							
Other							
	A COMPLETE PIPE PLANT			SPECIAL	NONE	VARIES	UNKNOWN

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

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OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Contact: Mr. Gary Aylor Date: 9/19/86

Title: Environmental Coordinator

Company Name: Cato Oil and Grease Company

Address: 915 North Eastern Avenue

City: Oklahoma City State: OK Zip Code: 73117

Telephone: (405) 424-3311

Asbestos products manufactured: Roof coatings

Approximate plant production capacity (for each product): 19,000 gal/yr (1984)

15,000 lb (1984 asbestos consumption)

Manufacturing products containing asbestos at present (Yes/No)? Yes

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).
2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

   Yes - Currently produce roof coatings which do not contain asbestos

3. Estimated time required to make conversion:

   None

4. Estimated cost of conversion:

   N/A

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

None

6. Is equipment useable for another industry (Yes/No)? Yes If Yes, please comment:

Lubrication industry - Use as a grease-blending kettle.

7. Can equipment be sold to foreign manufacturers (Yes/No)? N/A

8. Has equipment already been sold (Yes/No)? No

If Yes, please give name and address of purchaser

____

____

____

____

9. Estimated cost of equipment teardown/cleanup:

Minimal - Flush kettle between each product line with oil.

10. Would it be possible to arrange a future PEI visit (Yes/No)? Yes

What is the procedure for obtaining permission to arrange a site visit?

Mr. Gary Aylor

Note: N/A = Not applicable
N.A. = Not available

EQUIPMENT DATA
ASBESTOS COATING

Primary equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight (tons)[b]
Mixing tank (700 gal, 30-HP motor)[c]	3	20	d	5000	Unknown	Unknown	1 each
Total batch process - dry materials are added by hand to mixer - final product is poured by gravity from mixer into containers for sale							

[a] What would it cost to purchase this equipment new today (estimate)?
[b] Please indicate units if other than tons.
[c]
[d] Indefinite.

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N2-15 (17)

OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Contact: Guss Cook Date: 9/22/86

Title: Safety, Fire, Health Specialist

Company Name: Chevron U.S.A., Inc.

Address: 849 Standard Avenue

City: Richmond State: CA Zip Code: 94802

Telephone: (404) 955-1200

Asbestos products manufactured: None*

Approximate plant production capacity (for each product): N/A

Manufacturing products containing asbestos at present (Yes/No)? No

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

3. Estimated time required to make conversion:

4. Estimated cost of conversion:

* In early 1980's Chevron sold off all asphalt/sealing compound product lines to other companies. Some equipment was sold separately to other companies. Management decided to sell and discontinue a whole series of asphalt products due to low-volume sales/labor intensive. Had nothing to do with asbestos issue at that time.

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

6. Is equipment useable for another industry (Yes/No)? __________ If Yes, please comment:

7. Can equipment be sold to foreign manufacturers (Yes/No)? _________

8. Has equipment already been sold (Yes/No)? _______________

   If Yes, please give name and address of purchaser

   ____

   ____

   ____

   ____

9. Estimated cost of equipment teardown/cleanup:

10. Would it be possible to arrange a future PEI visit (Yes/No)? __________

    What is the procedure for obtaining permission to arrange a site visit?

Note: N/A = Not applicable
N.A. = Not available

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OPTS 62036 Asbestos Ban
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ASBESTOS PRODUCTS MA

62036
N2-15(18)

Contact: George D. Hayes

Date: 9/24/86

Title: Plant Manager

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Company Name: GARLOCK INC.-COMPRESSION PACKING DIV., COLT INDUSTRIES

Address: 300 Alling Drive

City: Sodus State: NY Zip Code: 14551

Telephone: (315) 483-6961

Asbestos products manufactured: Packings

Approximate plant production capacity (for each product): 500,000 Lbs./Yr.

Manufacturing products containing asbestos at present (Yes/No)? No

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

   Yes - our entire line of products was converted to non-asbestos.

3. Estimated time required to make conversion:

   No special conversion required - same equipment is being used today.

4. Estimated cost of conversion:

   N/A

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5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

   Operating rate and productivity relatively unchanged. Equipment would not have to be designed specifically for non-asbestos packing manufacturing.

6. Is equipment useable for another industry (Yes/No)? ________ If Yes, please comment:

   Equipment specifically used for packing manufacture is generally not usable by other industries. Equipment used to make ring forms from packing is usable in other industries.

7. Can equipment be sold to foreign manufacturers (Yes/No)? No

8. Has equipment already been sold (Yes/No)? No

   If Yes, please give name and address of purchaser

   ____

   ____

   ____

   ____

9. Estimated cost of equipment teardown/cleanup:

   N/A

10. Would it be possible to arrange a future PEI visit (Yes/No)? No

    What is the procedure for obtaining permission to arrange a site visit?

Note: N/A = Not applicable
N.A. = Not available

EQUIPMENT DATA
ASBESTOS GASKETS/PACKINGS

Primary equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight[b] (tons)
Braiders				5-45,000			
Calenders				10,000			
Impregnation systems				100,000			
Winders				10-35,000			
Twisters				15-35,000			
Cut-off Machines				10,000			
Presses				25,000			
Mixers				45,000			
Extruders				45 - 100,000			
Spoolers				10-20,000			
Blank Cutters				15-35,000			
Lub Tanks				2,500-5,000			

Note: Cost of equipment per unit ranges are dependent on size of machine purchased (depending on size of material to be produced) and extra options purchased. Some equipment is special and not available on the market. All prices are estimates.

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

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62036
N2-15(19)

OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Contact: Rex Farmer Date: 9/19/86

Title: Technical Director

Company Name: Concrete Sealants, Inc.

Address: 8917 S. Palmer Road

City: New Carlisle State: OH Zip Code: 45344

Telephone: (513) 845-8776

Asbestos products manufactured: Sealants for concrete waterproofing - prevent water penetration

Approximate plant production capacity (for each product): 2 to 3 x 10^6 lb/yr

Manufacturing products containing asbestos at present (Yes/No)? No

Have not used asbestos for 3 years.

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

   Yes - No equipment modification necessary.

3. Estimated time required to make conversion:

   Laboratory time - 10 months
   Plant time - No time, no equipment change required

4. Estimated cost of conversion:

   Approximately $100,000 - All R&D and plant trials

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

   No change, perhaps better - improve technique due to new equipment. New equipment added simply due to company growth.

6. Is equipment useable for another industry (Yes/No)? ___No___ If Yes, please comment:

7. Can equipment be sold to foreign manufacturers (Yes/No)? ___N/A___

8. Has equipment already been sold (Yes/No)? ___N/A___

   If Yes, please give name and address of purchaser

   ____

   ____

   ____

   ____

9. Estimated cost of equipment teardown/cleanup: N/A

10. Would it be possible to arrange a future PEI visit (Yes/No)? ___Yes___

    What is the procedure for obtaining permission to arrange a site visit?

    Bob Haman, Sr.
    President

Note: N/A = Not applicable
N.A. = Not available

EQUIPMENT DATA
ASBESTOS ADHESIVES/COATING

Primary equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight (tons)[b]
Baker-Perkins mixer	3	2	30	250,000-300,000	125,000	0	60 tons
Baghouse	1	5-6	15-20	70,000	10,000-20,000	0	N.A.

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

EQUIPMENT DATA
ASBESTOS ADHESIVES/COATING

Primary equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight (tons)[b]
Baker-Perkins mixer	3	2	30	250,000-300,000	125,000 ~~250,000~~	0	60 tons
Baghouse	1	5-6	15-20	70,000	10,000-20,000	0	N.A.

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

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OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Contact: Allan Morris Date: 9/22/86

Title: Technical Director

Company Name: Coopers Creek Chemical Corp.

Address: River Road

City: West Conshohocken State: PA Zip Code: 19428

Telephone: (215) 828-0375

Asbestos products manufactured: Roof coatings

Approximate plant production capacity (for each product): N.A. - very small operation

Manufacturing products containing asbestos at present (Yes/No)? Yes

By year end all products will be nonasbestos (presently trial basis for non-asbestos products)

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

   Yes, very easily.

3. Estimated time required to make conversion:

   Equipment is suitable, no time required to make conversion.

4. Estimated cost of conversion:

   Nonasbestos substitute more expensive - 30 to 40¢/gal

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

Operating rate reduced 20 percent - due to nature of nonasbestos material less efficient. Specifically designed equipment would naturally be more efficient.

6. Is equipment useable for another industry (Yes/No)? No If Yes, please comment:

7. Can equipment be sold to foreign manufacturers (Yes/No)? N/A

8. Has equipment already been sold (Yes/No)? N/A

If Yes, please give name and address of purchaser

____

____

____

____

9. Estimated cost of equipment teardown/cleanup: None

10. Would it be possible to arrange a future PEI visit (Yes/No)? Yes

What is the procedure for obtaining permission to arrange a site visit?

Al Morris

Note: N/A = Not applicable
N.A. = Not available

EQUIPMENT DATA
ASBESTOS COATING

Primary equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight (tons)[b]
Screw conveyor	2	30	10	N.A.	N.A.	N.A.	N.A.
Paddle mixer	2	5-6	10	N.A.	N.A.	N.A.	N.A.
Baghouse	2	10	10	N.A.	N.A.	N.A.	N.A.

[a] What would it cost to purchase this equipment new today (estimate)?
[b] Please indicate units if other than tons.

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PEI Survey/
OPTS 62036 Asbestos Ban
Written Comm N(2)-15(21) File

OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Contact: Pat McVickar

Date: Sept 29, 1986

62036
N_2-15(21)

Title: Facilities Engineer

Company Name: Victor Products Div.Dana Corp

Address: PO Box 599

South Eaton Road

City: Robinson State: IL Zip Code: 62454

Telephone: (618) 544-8651

Asbestos products manufactured: Compressed asbestos sheets

Approximate plant production capacity (for each product):

3,000,000 sq yds/yr

Manufacturing products containing asbestos at present (Yes/No)? Yes

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

   1. Cement mixers (yes)
   2. Body mixers (no)
   3. Processal & Littleford are purchased for non-asbestos
   4. Sheeter mills can be converted

3. Estimated time required to make conversion:

   2 years

4. Estimated cost of conversion:

   $20,000/sheeter mill

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

   To date, non-asbestos materials run much slower than the asbestos material. Other than the mixers, specifically designed machines have not been developed.

6. Is equipment useable for another industry (Yes/No)? No If Yes, please comment:

7. Can equipment be sold to foreign manufacturers (Yes/No)? ?

8. Has equipment already been sold (Yes/No)? No

   If Yes, please give name and address of purchaser

   ____

   ____

   ____

   ____

9. Estimated cost of equipment teardown/cleanup:

   $50,000

10. Would it be possible to arrange a future PEI visit (Yes/No)? Yes

    What is the procedure for obtaining permission to arrange a site visit?

    1. Call for an appointment
    2. Depending on what you want to see, it may be necessary for a confidentially agreement

Note: N/A = Not applicable
N.A. = Not available

EQUIPMENT DATA
ASBESTOS GASKETS/PACKINGS

Primary equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight (tons)[b]
Single cement mixer	1	20	Unknown	90,000	Unknown	60	3
Triple cement mixer	2	20		110,000		100	5
Double cement mixer	3	20		100,000		80	4
Body mixer B-P	1	21		90,000		80	4
Body mixer B-P	2	21		90,000		80	4
Body mixer B-P	3	21		90,000		80	4
Body mixer B-P	4	21		90,000		80	4
Body mixer processal	5	-0-		110,000		80	4
Body mixer Littleford	6	1		110,000		60	3
Sheeter mill 40x120	1	30		350,000		?	30
Sheeter mill 40x60	2	25		200,000		?	22
Sheeter mill 40x60	3	25		200,000		?	22
Sheeter mill 40x60	4	25		200,000		?	22
Sheeter mill 40x60	5	25		200,000		?	22
Sheeter mill 40x60	6	20		200,000		?	22
Sheeter mill 40x60	7	20		200,000		?	22
Sheeter mill 60x60	8	12		250,000		?	40
Sheeter mill 60x60	9	12		250,000		?	40

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

PEI Survey/
OPTS 62036 Asbestos Ban
Written Comm N(2)-15(22) File

1503

OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

62036
N2-15(2

Contact: Mr. John O'Brien   Date: 9/20/86

Title: EPA Contact Official

Company Name: GAF Corporation

Address: 2400 Emogene Street

City: Mobile   State: AL   Zip Code: 36606

Telephone: (201) 628-3509

Asbestos products manufactured: None

Approximate plant production capacity (for each product): N/A

*Manufacturing products containing asbestos at present (Yes/No)? No

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

3. Estimated time required to make conversion:

4. Estimated cost of conversion:

* Between 1981 and 1981 discontinued or sold off every product line that used asbestos.
Sold paper/millboard production to Quin-T Corp., Erie, PA.
Sold flooring product lines to Tarkett, Inc., who have discontinued using asbestos in the product - Headquarters are in Parsippany, NJ (201) 428-9000.

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

6. Is equipment useable for another industry (Yes/No)? __________ If Yes, please comment:

7. Can equipment be sold to foreign manufacturers (Yes/No)? __________

8. Has equipment already been sold (Yes/No)? _______________

   If Yes, please give name and address of purchaser

   ____

   ____

   ____

   ____

9. Estimated cost of equipment teardown/cleanup:

10. Would it be possible to arrange a future PEI visit (Yes/No)? __________

    What is the procedure for obtaining permission to arrange a site visit?

Note: N/A = Not applicable
N.A. = Not available

1505

PEI Survey/
OPTS 62036 Asbestos Ban
Written Comm N(2)-15(23) File

manufacturers of protective coatings • wallcovering adhesives

the GIBSON-HOMANS company
TWINSBURG DIVISION
1755 ENTERPRISE PARKWAY • TWINSBURG, OH 44087 • 216/425-3255

62036
N2-15(23)

2 October 1986

PEI Associates, Inc.
11499 Chester Road
Cincinnati, Ohio 45246

Attention: Mr. Ronald S. McKibben

Re: OTS Asbestos Products Survey

Dear Ron:

I passed the enclosed survey form on to my supervisors; they have declined to provide the requested information.

The only statement the Gibson-Homans Company chooses to make at this time is: All our products are asbestos-free; we are using the same manufacturing equipment as for asbestos containing products. Any further information is considered proprietary and confidential.

Ron, I'm sorry I could not be of more assistance to you on this.

Regards,

William D. Petersen
Technical Service Representative

WDP/sv

1505 A

PEI Survey/
OPTS 62036 Asbestos Ban
Written Comm N(2)-15(23) File

OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Contact: MR. BILL PETERSEN Date: 9/19/86

Title: TECHNICAL SERVICE REPRESENTATIVE

Company Name: GIBSON-HOMANS COMPANY

Address: 1755 ENTERPRISE PARKWAY

City: TWINSBURG State: OHIO Zip Code: 44087

Telephone: 216/425-3255

(PAST) — Asbestos products manufactured: ROOF COATINGS, SEALANTS, ADHESIVES

Approximate plant production capacity (for each product):

Manufacturing products containing asbestos at present (Yes/No)? NO

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

3. Estimated time required to make conversion:

4. Estimated cost of conversion:

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

6. Is equipment useable for another industry (Yes/No)? __________ If Yes, please comment:

7. Can equipment be sold to foreign manufacturers (Yes/No)? _________

8. Has equipment already been sold (Yes/No)? _______________

   If Yes, please give name and address of purchaser

   ____

   ____

   ____

   ____

9. Estimated cost of equipment teardown/cleanup:

10. Would it be possible to arrange a future PEI visit (Yes/No)? __________

    What is the procedure for obtaining permission to arrange a site visit?

Note: N/A = Not applicable
N.A. = Not available

EQUIPMENT DATA

ASBESTOS ADHESIVES/SEALANTS/COATING

Primary equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight (tons)[b]

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

EQUIPMENT DATA
ASBESTOS ADHESIVES/SEALANTS/COATING

Primary equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight (tons)[b]

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

EQUIPMENT DATA

ASBESTOS ADHESIVES/SEALANTS/COATING

Primary equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight (tons)[b]

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

1504

PEI Survey/
OPTS 62036 Asbestos Ban
Written Comm N(2)-15(24) File

62036
N_2-15(24)

OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Contact: F. Wayne Donnell Date: 9/15/86

Title: Purchasing Manager

Company Name: H. K. Porter Co., Inc.

Address: 1849 Sabine Street

City: Huntington State: Indiana Zip Code: 46750

Telephone: (219) 356-2410

Asbestos products manufactured: Drum brake linings, brake blocks, friction materials & clutch facings - after market auto industry & other industrial users.

Approximate plant production capacity (for each product): N.A.

-Job shop; 130,000 ft² facility with no production lines per se; 120 employees at present - has been as high as 400.

Manufacturing products containing asbestos at present (Yes/No)? Yes (until end of year)

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

   Same equipment used in general - just different material used.

3. Estimated time required to make conversion:

   N.A.

4. Estimated cost of conversion:

   N.A.

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

N.A.

6. Is equipment useable for another industry (Yes/No)? No If Yes, please comment:

7. Can equipment be sold to foreign manufacturers (Yes/No)? Yes (probably)

8. Has equipment already been sold (Yes/No)? No

If Yes, please give name and address of purchaser

N/A

9. Estimated cost of equipment teardown/cleanup:

N.A.

10. Would it be possible to arrange a future PEI visit (Yes/No)? Yes

What is the procedure for obtaining permission to arrange a site visit?

Work through Paul Stratton, General Manager

Note: N/A = Not applicable
N.A. = Not available

EQUIPMENT DATA
ASBESTOS FRICTION MATERIALS

Equipment item/area	Number	Age* (yrs)	Useful life (yrs)**	Cost for same equipment today ($)[a]	Resale value*** ($)	Scrap value ($)	Equipment weight (tons)[b]
Mixer				N.A.		N.A.	N.A.
Preform compression molding machines				N.A.		N.A.	N.A.
Heated compression molding machines				N.A.		N.A.	N.A.
Combination slitter and cutter				N.A.		N.A.	N.A.
Arc-forming molding machine				N.A.		N.A.	N.A.
Curing oven				N.A.		N.A.	N.A.
Finishing equipment (drills, grinders, etc.)				N.A.		N.A.	N.A.
Other							
Other							
Other							
Other							
Other							

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

* Could not specify - said 3 to 30 years.

** Indefinite - equipment doesn't wear out and state of art not changed enough to make obsolete.

*** Very little to no value - particularly to other industries.

PEI Survey/
OPTS 62036 Asbestos Ban
Written Comm N(2)-15(25) File

1507

62036
N2-15(25)

OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Contact: Mr. Arthur Purdy   Date: 9/19/86

Title: Plant Manager

Company Name: Karnak Chemical Corp.

Address: 330 Central Avenue

City: Clark   State: NJ   Zip Code: 07066

Telephone: (201) 388-0300

Asbestos products manufactured: Asphalt roof coatings and water sealants

Approximate plant production capacity (for each product): *6,240,000 gal/yr

Manufacturing products containing asbestos at present (Yes/No)? Yes

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

   Yes

3. Estimated time required to make conversion:

   Take lump breaker out
   Clean mixer
   Clean the system
   4 to 5 hours, 2 men

4. Estimated cost of conversion:

   Unknown

* Estimated from 600-can/h production rate of machine, operating 5 days/wk, 8 h/day, filling 5-gallon pails.

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

Little longer to make product due to mixing properties of new ingredients.

6. Is equipment useable for another industry (Yes/No)? Yes If Yes, please comment:

Mixer could be used in paint industry.

7. Can equipment be sold to foreign manufacturers (Yes/No)? No

8. Has equipment already been sold (Yes/No)? No

If Yes, please give name and address of purchaser

____

____

____

____

9. Estimated cost of equipment teardown/cleanup:

5 hours - two men

10. Would it be possible to arrange a future PEI visit (Yes/No)? Yes

What is the procedure for obtaining permission to arrange a site visit?

Mr. Arthur Purdy

Note: N/A = Not applicable
N.A. = Not available

EQUIPMENT DATA
ASBESTOS ADHESIVES/SEALANTS/COATING

Primary equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight (tons)[b]
Automatic bag slitter	1	1[c]	15		Unknown	Unknown	Unknown
Lump breaker[d]	1	12	8		Unknown	Unknown	Unknown
Pneumatic conveyors	1	12	8		Unknown	Unknown	Unknown
Mixer	4	12	5		Unknown	Unknown	Unknown
Baghouse	1	12	8		Unknown	Unknown	Unknown
Automatic filling machine	2	12	8		Unknown	Unknown	Unknown
			Total cost	500,000	Unknown	Unknown	Unknown

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

[c] Was recently replaced.

[d] Performs same function as a fluffing machine.

1508

PEI Survey/
OPTS 62036 Asbestos Ban
Written Comm N(2)-15(26) File

62036
N2-15(26)

OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Contact: Mr. Donald Cardner Date: 9/23/86

Title: Plant Manager

Company Name: Kirkhill Rubber Company

Address: 300 East Cypress Street

City: Berea State: CA Zip Code: 92612

Telephone: (714) 529-4901

Asbestos products manufactured: Rubber liners for solid rocket booster engines, including the NASA space shuttle

Approximate plant production capacity (for each product): Confidential

Manufacturing products containing asbestos at present (Yes/No)? Yes

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

   NA*

3. Estimated time required to make conversion:

   Have yet to find substitute material.

4. Estimated cost of conversion:

   NA

* NA = Not available due to being confidential.

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

Unknown at this time.

6. Is equipment useable for another industry (Yes/No)? __________ If Yes, please comment:

NA

7. Can equipment be sold to foreign manufacturers (Yes/No)? NA

8. Has equipment already been sold (Yes/No)? NA

If Yes, please give name and address of purchaser

____

____

____

____

9. Estimated cost of equipment teardown/cleanup:

NA

10. Would it be possible to arrange a future PEI visit (Yes/No)? No

What is the procedure for obtaining permission to arrange a site visit?

Confidential process

Note: N/A = Not applicable
N.A. = Not available

EQUIPMENT DATA

Primary equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight (tons)[b]
Confidential enclosing whole process (installing glove boxes to handle asbestos)							

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

PEI Survey/
OPTS 62036 Asbestos Ban
Written Comm N(2)-15(27) File

1509

62036
N2-15(27)

OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Contact: Delvin Foster Date: 9/23/86

Title: Purchasing Manager

Company Name: LSI-Certified Brakes

Address: Stewart's Lane

City: Danville State: Kentucky Zip Code: 40422

Telephone: (606) 236-8224

Asbestos products manufactured: Light & medium duty vehicle disc brake pads and brake drum linings.

Approximate plant production capacity (for each product): ~300 employees in 3 shifts; 8.32×10^6 pieces/year manufactured.

Manufacturing products containing asbestos at present (Yes/No)? Yes*

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

   Same equipment used. Asbestos substitute materials cause more wear in equipment otherwise basically the same operation.

3. Estimated time required to make conversion:

   The only work required was some modifications to a few of the presses that was completed in less than a week.

4. Estimated cost of conversion:

   Minimal.

* Currently 70% of production consists of asbestos-based products.

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

   The production capacity of equipment using the asbestos substitute material dropped to 40% of what it was prior to the conversion.

6. Is equipment useable for another industry (Yes/No)? ___Yes___ If Yes, please comment:

   It is possible that much of the equipment could be used by a company producing similar products in the friction products industry but not in another industry.

7. Can equipment be sold to foreign manufacturers (Yes/No)? N.A. (Foster didn't know)

8. Has equipment already been sold (Yes/No)? ___No___

   If Yes, please give name and address of purchaser

   ___N/A___

9. Estimated cost of equipment teardown/cleanup:

   N.A.

10. Would it be possible to arrange a future PEI visit (Yes/No)? ___Yes*___

    What is the procedure for obtaining permission to arrange a site visit?

Note: N/A = Not applicable
N.A. = Not available

* Would have to be approved through proper channels but Foster felt there would be no major problems.

EQUIPMENT DATA
ASBESTOS FRICTION MATERIALS

Equipment item/area	Number	Age* (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight (tons)[b]
Mixer	3			N.A.	N.A.	N.A.	N.A.
Preform compression molding machines	7			N.A.	N.A.	N.A.	N.A.
Heated compression molding machines	12			N.A.	N.A.	N.A.	N.A.
Combination slitter and cutter	-	-	-	-	-	-	-
Arc-forming molding machine	-	-	-	-	-	-	-
Curing oven	3			N.A.	N.A.	N.A.	N.A.
Finishing equipment (drills)	8			N.A.	N.A.	N.A.	N.A.
Finishing equipment (grinders)	4			N.A.	N.A.	N.A.	N.A.
Other							
Other							
Other							
Other							
Other							
Average:		12-15	~10				

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

* Range: 10-20 years.

PEI Survey/
OPTS 62036 Asbestos Ban
Written Comm N(2)-15(28) File

1510

62036
N_2-15(28)

OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Contact: Bob Andrews Date: 9/30/86

Title: General Manager

Company Name: Magnolia Plastics

Address: 5547 Peachtree Industrial Blvd.

City: Chamblee State: GA Zip Code: 30341

Telephone: (404) 451-2777

Asbestos products manufactured: Asbestos reinforced plastics (epoxy compounds)

Approximate plant production capacity (for each product): Total capacity 8×10^6 lb of which 300,000 lb are thickened plastics, rest are fluid plastics

Manufacturing products containing asbestos at present (Yes/No)? Yes

Thickened products can contain asbestos or asbestos substitute (Cav-O-Sil). Fifty percent of thickened products use Cav-O-Sil. Asbestos is used since it renders the product very stable (approximately 1 year).

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

   If Cav-O-Sil is used as substitute, the same equipment can be used. The problem with this substitute is that it is not very stable (stable for approximately 1 month). Another substitute, Bentone, is much more stable (stable for approximately 6 months) but would require 3 roll mills. These roll mills would cost \$25,000-\$50,000 used, 2 to 3 times more if purchased new. Currently investigating use of Bentone.

3. Estimated time required to make conversion:

   Best guess is 1 year to reformulate products.

4. Estimated cost of conversion:

   See question 2. If Cav-O-Sil is used, there would be no capital cost incurred. Costs would simply be researched to reformulate product.

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

   Asbestos is much better than substitutes in all aspects except health and safety. No information on comparison between converted and specifically-designed equipment.

6. Is equipment useable for another industry (Yes/No)? ___Yes___ If Yes, please comment:

   Paint and rubber industry uses similar equipment.

7. Can equipment be sold to foreign manufacturers (Yes/No)? ___N/A___

8. Has equipment already been sold (Yes/No)? ___N/A___

   If Yes, please give name and address of purchaser

   ____

   ____

   ____

   ____

9. Estimated cost of equipment teardown/cleanup:

   No cleanup or tear-down costs are incurred. The mixers would simply be used for other products.

10. Would it be possible to arrange a future PEI visit (Yes/No)? ___Yes___

    What is the procedure for obtaining permission to arrange a site visit?

    Bob Andrews

Note: N/A = Not applicable
N.A. = Not available

EQUIPMENT DATA
ASBESTOS REINFORCED PLASTICS

Primary equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight (tons)[b]
Baghouse	1	10-12	"Long time"	10-15,000	0	0	N/A
Cowles dissolvers-mixers[c]	6	5-20	10	10-15,000	N.A	N.A.	N.A

[a] What would it cost to purchase this equipment new today (estimate)?
[b] Please indicate units if other than tons.
[c] Asbestos manually dumped into mixer.
N/A Not applicable.
N.A. Not available.

1511

62036
N2-15(29)

OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Contact: Mr. LeRoy McDonald Date: 10/7/86

Title: Senior Consultant Product Safety

Company Name: Mead Corporation

Address: Courthouse Plaza, Northeast
Plant in South Lee, MA

City: Dayton State: OH Zip Code: 45463

Telephone: 513/439-9230

Asbestos products manufactured: None[a]

Approximate plant production capacity (for each product):
Confidential

Manufacturing products containing asbestos at present (Yes/No)? No

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

   Yes. No change in paper production equipment necessary with substitute; only difference was the engineering controls used for asbestos which are now "over designed" for the fibers in use today (e.g., baghouses more complex).

3. Estimated time required to make conversion:

   Developmental/research time: 4 years.

   Conversion time: 2 to 4 weeks (cleanup of equipment and acquiring stock material for production).

[a] Use to produce asbestos friction paper for use in automatic transmissions - stopped production of asbestos-containing friction paper in December 1983.

4. Estimated cost of conversion:

   Developmental: manufacturer ($200,000 - 3 full-time technicians working 4 years); customer: car manufacturers ($500,000 - 4 years of research/development, testing of prototype transmissions, etc.); engineering control costs: $300,000 - the difference between what is needed today versus that needed for asbestos (i.e., $200,000 versus $500,000); cleanup cost - $30,000.

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

   No change in operating rate/productivity with substitute - only higher material cost due to use of synthetic fibers as substitute.

6. Is equipment useable for another industry (Yes/No)? ___Yes___ If Yes, please comment:

   Any paper industry product line.

7. Can equipment be sold to foreign manufacturers (Yes/No)? ___Yes___

8. Has equipment already been sold (Yes/No)? ___No___

   If Yes, please give name and address of purchaser

   ____

   ____

   ____

   ____

9. Estimated cost of equipment teardown/cleanup:

   Outside contractor was hired to vacuum all equipment, storage rooms, walls, ductworks, overhead beams, etc. Using high efficiency HEPA Vacs - some equipment were washed with water - took 1.5 weeks at approximately $30,000. Company officials monitored the cleanup process and dust analysis. Only respirators were worn - no clean suits or containment areas were necessary.

10. Would it be possible to arrange a future PEI visit (Yes/No)? ___No___

    What is the procedure for obtaining permission to arrange a site visit?

Note: N/A = Not applicable
      N.A. = Not available

EQUIPMENT DATA
ASBESTOS PAPERS/FELTS

Equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight (tons)[b]
Asbestos (warehouse)							
Cellulose (warehouse)							
Starch (silo)							
Hydropulper							
Holding chest							
Stock pump							
Machine chest							
Refiner							
Jordan							
Cylinder type papermaking machine (or fourdriniers)							
Dryer section with dryer felts							
Calendar rolls							
Felt whipper							
3-reel winder							
Unwinder							
Slitter							
Roll wrapper							
Boiler							
Other ______							
Other ______							
Other ______							
Other ______							
Other ______							

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

N/A. All equipment used to make asbestos containing friction paper is still in use today with substitute.

1512

PEI Survey/
OPTS 62036 Asbestos Ban
Written Comm N(2)-15(30) File

62036
N2-15(30)

EPA/OTS
TSCA PUBLIC FILE

1986 NOV -5 AM 9:14

OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Contact: Robert Tami Date: 10/23/86

Title: Safety Engineer

Company Name: Motion Control Industries

Address: Gillis Avenue

P.O. Box P

City: Ridgeway State: PA Zip Code: 15853

Telephone: (814) 773-3185

Asbestos products manufactured: Disc brake pads (heavy duty) - 1%; heavy duty brake blocks - 99%.

Approximate plant production capacity (for each product): 30,000 pieces/day currently (approximately 75% capacity).

Manufacturing products containing asbestos at present (Yes/No)? Yes*

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

   Same equipment - because of the new asbestos substitute formulations developed no modifications were made at all except for the small brake pad operations where simimetalics are used.

3. Estimated time required to make conversion:

   Work began in 1977 - took 5 years to come up with acceptable substitute products. No time for equipment conversion since no actual conversion was made. The new formulations include different additives, mineral wool, kevlar and fiberglass. Metallics used only in pad products.

* 90% asbestos substitutes. Will be 100% by November 16 (new OSHA regulations take effect on 11/16).

4. Estimated cost of conversion:

No equipment cost but required 3-4 full time employees in R&D for 3-5 years. Minimal equipment costs - some trial and error on equipment applications. Materials are more experience.**

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

No change in production efficiency (except for the small pad operations). The new asbestos substitutes actually are less abrasive so equipment wear is reduced. The metallic products are a problem - compressibility problems heavier, don't hold together, harder to work with.

6. Is equipment useable for another industry (Yes/No)? Yes If Yes, please comment:

Blenders, hydraulic presses, pottered presses and grinding wheels could be used but most equipment is unique to the friction products industry.

7. Can equipment be sold to foreign manufacturers (Yes/No)? Yes (in friction products industry).

8. Has equipment already been sold (Yes/No)? No

If Yes, please give name and address of purchaser

N/A

9. Estimated cost of equipment teardown/cleanup:

Clean up would be ~100,000; teardown N.A.

10. Would it be possible to arrange a future PEI visit (Yes/No)? Yes*

What is the procedure for obtaining permission to arrange a site visit?

---

* Would have to go through management channels.

** Cost of Fibers/Materials: Asbestos - 15¢/lb
Fiberglass - 60¢/lb
Mineral wool - 25¢/lb
Kevlar - $5/lb

Note: N/A = Not applicable
N.A. = Not available

NOTE: The asbestos substitutes now used at this facility are better than the asbestos materials. They meet the same standards for friction and other performance characteristics but last 30-40% longer and do not cause as much wear on brake drums - not as abrasive as asbestos. This is true for all but the brake pad products.

EQUIPMENT DATA
ASBESTOS FRICTION MATERIALS

Equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight (tons)[b]
Mixer	4	15-20	>20	N.A.	N.A.	N.A.	N.A.
Preform compression molding machines	10	~20	>20	N.A.	N.A.	N.A.	N.A.
Heated compression molding machines (hot presses)	50	~20	>20	N.A.	N.A.	N.A.	N.A.
Combination slitter and cutter	6	~20	>20	N.A.	N.A.	N.A.	N.A.
Curing oven	4	~20	>20	N.A.	N.A.	N.A.	N.A.
Finishing equipment (drills, grinders, etc.)		~20	>20	N.A.	N.A.	N.A.	N.A.
Other I.D. Grinders	10	~20	>20	N.A.	N.A.	N.A.	N.A.
Other O.D. Grinders	10	~20	>20	N.A.	N.A.	N.A.	N.A.
Other Bag Houses (30K CFM)	8	~20	>20	N.A.	N.A.	N.A.	N.A.
Other Dynamometers	2	~20	>20	N.A.	N.A.	N.A.	N.A.
Other							

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

PEI Survey/
OPTS 62036 Asbestos Ban File
Written Comm N(2)-15(31)

62036
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1513

OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Date: 9/17/86

Contact: E. J. Snyder (also Rex Keiser)

Title: General Manager (Vice President)

Company Name: National Friction Products

Address: 11411 Holland Street

City: Logansport State: Indiana Zip Code: 46947

Telephone: (219) 753-6391

Asbestos products manufactured: Clutch facings & brake drum linings for heavy industry, off road vehicles, RVs, lawn care, agriculture & appliance manufacturing friction products.

Approximate plant production capacity (for each product): N.A.

Manufacturing products containing asbestos at present (Yes/No)? Yes

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

   Yes - National Friction Products has already moved 60% of production to non-asbestos-based products. Same equipment with minor modifications.

3. Estimated time required to make conversion:

   Minimal

4. Estimated cost of conversion:

   N.A.

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

   No significant difference noted in production throughput. Wear and maintenances levels increased.

6. Is equipment useable for another industry (Yes/No)? ___N.A.___ If Yes, please comment:

7. Can equipment be sold to foreign manufacturers (Yes/No)? ___N.A.___

8. Has equipment already been sold (Yes/No)? ___No___

   If Yes, please give name and address of purchaser

   ___N/A___

9. Estimated cost of equipment teardown/cleanup:

   N.A.

10. Would it be possible to arrange a future PEI visit (Yes/No)? ___Yes*___

    What is the procedure for obtaining permission to arrange a site visit?

    Clear through Rex Keiser or E.J. Snyder.

Note: N/A = Not applicable
N.A. = Not available

* Not permitted in some proprietary areas.

EQUIPMENT DATA
ASBESTOS FRICTION MATERIALS
- N.A.* -

Equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight (tons)[b]
Mixer							
Preform compression molding machines							
Heated compression molding machines							
Combination slitter and cutter							
Arc-forming molding machine							
Curing oven							
Finishing equipment (drills, grinders, etc.)							
Other							
Other							
Other							
Other							
Other							

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

* Not available because of confidentiality concerns.

1514

PEI Survey/
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62036
N_2-15(32)

OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Contact: Mr. Bob Bair Date: 9/23/86

Title: Plant Manager

Company Name: National Varnish Co.

Address: 609 St. Jean Street

City: Detroit State: MI Zip Code: 48214

Telephone: (313) 823-7500

Asbestos products manufactured: Asphalt roof coatings

Approximate plant production capacity (for each product): 1,500,000 gallons

Manufacturing products containing asbestos at present (Yes/No)? No

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

   Yes - already have - stopped using asbestos in March of this year.

3. Estimated time required to make conversion:

   No equipment modifications

   6-year period of trying to find substitute and quality supplier.

4. Estimated cost of conversion:

   No costs associated with equipment, but hard to estimate costs associated with finding new substitute material.

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

Much slower due to charging of variety raw materials versus just charging one.

6. Is equipment useable for another industry (Yes/No)? Yes If Yes, please comment:

Mixers could be sold to other roof coating companies or to paint industry - said it was easy to buy/sell used equipment.

7. Can equipment be sold to foreign manufacturers (Yes/No)? No

8. Has equipment already been sold (Yes/No)? No

If Yes, please give name and address of purchaser

Any used equipment is usually kept and usually

later used somewhere in their process

9. Estimated cost of equipment teardown/cleanup:

Minimal

10. Would it be possible to arrange a future PEI visit (Yes/No)? No

What is the procedure for obtaining permission to arrange a site visit?

Due to insurance reasons

Note: N/A = Not applicable
N.A. = Not available

EQUIPMENT DATA

Primary equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight (tons)[b]
Mixer (1500-gallon)	2	30	Indefinite[c]	20,000	500	Equipment never sold as scrap material, always sold to asphalt industry or paint industry	
Baghouse	1	7	Indefinite[d]	7,000	500		
1 hood	1	7	Indefinite	Included above	0		
1 hopper (charging)	1	7	Indefinite	500	0		

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

[c] Gear box repaired every winter. Beargings repaired every 6 years.

[d] Change begs every year.

PEI Survey/
OPTS 62036 Asbestos Ban
Written Comm N(2)-15(33) File

Various Products
AC Sheet
Gaskets
Saturated roofing felt
Still using asbestos in some products

1515

NICOLET, I

Wissahickon Ave.
Ambler, Pennsylvania 19002
(215) 646-4000

62036
N_2-15(33)

October 21, 1986

Mr. Ronald S. McKibben
PEI Associates, Inc.
11499 Chester Road
Cincinnati, Ohio 45246

RE: EPA Contract No. 68-02-4248
PEI PN 3687-23

Dear Mr. McKibben:

This will confirm our conversation of October 17, 1986. We do not have readily available the information you requested nor do we have the necessary man hours available to develop and assemble this data.

Very Truly Yours,
Nicolet, Inc.

Lawrence R Lo Russo

Lawrence R. LoRusso
Vice President of Finance

LRL/rcw

15 / 16

PEI Survey/
OPTS 62036 Asbestos Ban
Written Comm N(2)-15(34) File

62036
N_2-15(34

OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Contact: Sam Samson

Date: 9/18/86

Title: Plant Supt.

Company Name: Quin-T Corporation (PA)*

Address: 140 East 16th Street

City: Erie State: PA Zip Code: 16512

Telephone: (814) 453-5731

Asbestos products manufactured: Asbestos paper - base material for gaskets, etc.

Approximate plant production capacity (for each product): 14×10^6 lb - big machine 2×10^6 bl - small machine

Manufacturing products containing asbestos at present (Yes/No)? Yes

Quin-T manufactures both asbestos and nonasbestos products.

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

   Are currently making nonasbestos paper. Small cylinder machine 20 percent asbestos products. Big cylinder machine 70 percent asbestos products.

3. Estimated time required to make conversion:

   1 to 1½ months

4. Estimated cost of conversion:

   Cost to remove all traces of asbestos $10,000-$15,000

   $7000 to convert 2 cylinder from asbestos to nonasbestos - modified vat (pickup for paper).

* Plant was originally owned by the GAF Corporation.

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

Depends on customer requirements. Not much modification of equipment required.

6. Is equipment useable for another industry (Yes/No)? Yes If Yes, please comment:

7. Can equipment be sold to foreign manufacturers (Yes/No)? N/A

8. Has equipment already been sold (Yes/No)? N/A

If Yes, please give name and address of purchaser

____

____

____

____

9. Estimated cost of equipment teardown/cleanup: N/A

10. Would it be possible to arrange a future PEI visit (Yes/No)? Yes

What is the procedure for obtaining permission to arrange a site visit?

Contact William Samson.

Note: N/A = Not applicable
N.A. = Not available

EQUIPMENT DATA
ASBESTOS PAPERS/FELTS

Equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight (tons)[b]
Asbestos (warehouse)	1	80	20+	N.A.	N.A.	N.A.	N.A.
Cellulose (warehouse)	1	80	20+	N.A.	N.A.	N.A.	N.A.
Starch(silo)	1	13	40+	N.A.	N.A.	N.A.	N.A.
Hydropulper	1	13	40+	~350,000	N.A.	N.A.	N.A.
Holding chest	1	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Stock pump	10	c	c	~3,000	N.A.	N.A.	N.A.
Machine chest	1	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Refiner	1	d	10-15+	N.A.	N.A.	N.A.	N.A.
Jordan	1	d	30+	N.A.	N.A.	N.A.	N.A.
Cylinder type papermaking machine (or fourdriniers)	2[e]	f	20+	N.A.	N.A.	N.A.	N.A.
Steam dryer section	15	g	20-30+	N.A.	N.A.	N.A.	N.A.
Calendar stacks	2	2,3	30-40+	¼ to 1 million	N.A.	N.A.	N.A.
Felt whipper	0						
3-reel winder	2	20	20-30+	N.A.	N.A.	N.A.	N.A.
Unwinder (rewinder)	1	12-13[h]	20-30	N.A.	N.A.	N.A.	N.A.
Slitter	1	1[h]	N.A.	N.A.	N.A.	N.A.	N.A.
Roll wrapper	0				N.A.	N.A.	N.A.
Boiler	1	13	40-50+	N.A.	N.A.	N.A.	N.A.
Other							
Other							
Other							
Other							
Other							

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

[c] Equipment of all different ages.

[d] 2 years ago bought used.

[e] One small cylinder machine, one large cylinder machine.

[f] Small cylinder machine 25 to 30 years old. Large cylinder machine 20 years old.

[g] 18 are 10 years old, no data on other equipment.

[h] Purchased used equipment.

PEI Survey/
OPTS 62036 Asbestos Ban
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62036
N_2-15(35)

OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Contact: George Houser Date: 10/14/86

Title:

Company Name: Raymark Corporation

Address: 123 East Stiegel Street

City: Manheim State: PA Zip Code: 17545

Telephone: (717) 665-2211

Asbestos products manufactured: Clutch facings; heavy, light & medium duty vehicle disc brake pads & drum linings; other friction materials.

Approximate plant production capacity (for each product):
12×10^6 pieces per year total

Manufacturing products containing asbestos at present (Yes/No)? Yes*

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

   Basically the same equipment with some retooling and the addition of treating tunnels.

3. Estimated time required to make conversion:

   Continual - No specifics on time given.

4. Estimated cost of conversion:

   Treatment tunnels cost roughly $\$0.5 \times 10^6$, new clutch face molds cost about \$2000-\$3000 each-roughly 100 have been replaced. Another $\$1.5 \times 10^6$ will be incurred to completely convert the facility to asbestos substitute production.

* 50% of production now converted over to asbestos substitutes.

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

   Through put will drop. Baking and other process cycle times have gone up 10% after conversion.

6. Is equipment useable for another industry (Yes/No)? ___No___ If Yes, please comment:

7. Can equipment be sold to foreign manufacturers (Yes/No)? ___No___

8. Has equipment already been sold (Yes/No)? ___No___

   If Yes, please give name and address of purchaser

   ___N/A___

9. Estimated cost of equipment teardown/cleanup:

   Rough estimate was greater than $\$2x10^6$

10. Would it be possible to arrange a future PEI visit (Yes/No)? ___Yes___

    What is the procedure for obtaining permission to arrange a site visit?

    Will have to clear through management.

Note: N/A = Not applicable
N.A. = Not available

EQUIPMENT DATA
ASBESTOS FRICTION MATERIALS

Equipment item/area	Number	Age* (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight (tons)[b]
Mixer	20						
Preform compression molding machines	40						
Auto injection molding machines	2						
Combination slitter and cutter	4						
Bend slat machines	15						
Curing oven	40						
Finishing equipment (drills)	100						
Finishing equipment (finishings)	100						
Other Extruders	3						
Other Treating Towers	3						
Other Looms (for weaving materials)	40						
Other Carding Lines	4						
Other Lathes & Tumblers	N.A.						
Total/Average		30	30+	$50 mm	$10 mm	$.5 mm	N.A.

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

[c] 1 to 50 years - 30 years average.

NOTE: Most equipment areas are hooded - exhaust gases fed to 40 bag houses. This equipment would still be used if the company changed over to 100% asbestos substituted.

PEI Survey/
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N_2-15(36)

OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Contact: Jan Morris Date: 9/23/86

Title: Sr. Manufacturing Engineer

Company Name: Raymark Corporation

Address: 1204 Darlington Avenue

City: Crawfordsville State: Indiana Zip Code: 47933

Telephone: (317) 362-3500

Asbestos products manufactured: Clutch facings; auto transmission components; disc brake pads & brake drum linings for light & medium duty vehicles; and other friction products.

Approximate plant production capacity (for each product): N.A.

Manufacturing products containing asbestos at present (Yes/No)? Yes*

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

   Same equipment used. Machineability problems with some products drives costs up other products show no major manufacturing cost increase as a result of moving toward asbestos substitute materials.

3. Estimated time required to make conversion:

   A major time constraint sited was the lead time required to test new materials used in transmissions so that complete transmission recalibration can be performed.** This can take more than a year for a given transmission model.

* Moving production away from asbestos based products.

** Frictional forces well-known for asbestos based products. The asbestos substitutes are very different. Automobile manufacturers don't want to change materials on existing transmissions. They will be more willing to change as new models are introduced. Raymark is somewhat at the mercy of the companies they supply.

4. Estimated cost of conversion:

N.A.

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

N.A.

6. Is equipment useable for another industry (Yes/No)? No If Yes, please comment:

7. Can equipment be sold to foreign manufacturers (Yes/No)? No (not certain)

8. Has equipment already been sold (Yes/No)? No

If Yes, please give name and address of purchaser

N/A

9. Estimated cost of equipment teardown/cleanup:

10. Would it be possible to arrange a future PEI visit (Yes/No)? No*

What is the procedure for obtaining permission to arrange a site visit?

Note: N/A = Not applicable
N.A. = Not available

* Very competitive industry - processes are confidential.

EQUIPMENT DATA
ASBESTOS FRICTION MATERIALS

Equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight (tons)[b]
Mixer	2						
Preform compression molding machines	N.A.						
Heated compression molding machines	N.A.						
Combination slitter and cutter	N.A.						
Arc-forming molding machine	N.A.						
Curing oven	N.A.						
Finishing equipment (drills, grinders, etc.)	N.A.						
Other							
Other							
Other							
Other							
Other							
Total/Average		20	20	\$30-40 mm	N.A.	N.A.	N.A.

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

Raymark
INDUSTRIAL DIVISION

PEI Survey/
OPTS 62036 Asbestos Ban
Written Comm N(2)-15(37)(001) File

UNARCO ROAD, MARSHVILLE, NORTH CAROLINA 28103 (704) 624-5031

1519

62036
N2-15(37)

October 23, 1986

Chris Meyer
PEI Associates, Inc.
11499 Chester Road
Cincinnati, Ohio 45246

Dear Mr. Meyer:

Enclosed is the information you have requested.

Sincerely,

Lewis C Williams /hh

Lewis C. Williams

/hh

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PEI Survey/
OPTS 62036 Asbestos Ban
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N2-15(37)

OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Contact: Lewis C. Williams Date: 10/22/86

Title: Process Engineer

Company Name: Raymark Industrial Division

Address: Unarco Road

P.O. Box 429

City: Marshville State: N.C. Zip Code: 28103

Telephone: 704/624-5031

Asbestos products manufactured: Yarn for friction products

Approximate plant production capacity (for each product): 6,000,000 pounds per year.

Manufacturing products containing asbestos at present (Yes/No)? yes

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

   yes

3. Estimated time required to make conversion:

   4 - 6 weeks per card - total cards 18.

4. Estimated cost of conversion:

   $15,000.00 to $20,000.00 per card - total cards 18

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

After conversion 20 - 25 pounds/hour/card, was 70 - 90 pounds/hour/card. Favorably.

6. Is equipment useable for another industry (Yes/No)? No If Yes, please comment:

7. Can equipment be sold to foreign manufacturers (Yes/No)? Don't know

8. Has equipment already been sold (Yes/No)? No

If Yes, please give name and address of purchaser

____

____

____

____

9. Estimated cost of equipment teardown/cleanup: Don't know.

10. Would it be possible to arrange a future PEI visit (Yes/No)? Don't know

What is the procedure for obtaining permission to arrange a site visit?

Contact Bob Cleveland - President Raymark - Manheim Pa. 717/665-2211

Note: N/A = Not applicable
N.A. = Not available

EQUIPMENT DATA
ASBESTOS TEXTILES

Primary equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight (tons)[b]
Blendline	2	20	40	40,000.00		320.00	4
Card (Wooler Card)	18	40	70	720,000.00		2,880.00	36
Spinning (Roving Frame)	34	60	100	1,496,000.00		2,700.00	34
Winding (Foster 77)	10	40	80	75,000.00		480.00	6
Wheelabrator Collectors	6	18	50	1,800,000.00		1,440.00	18
Boiler - 500 HP	1	11	40	75,000.00		800.00	10
Wing Make-Up	8	11	40	40,000.00		480.00	6

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

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N2-15(38)

OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Contact: Mr. Robert Denes   Date: 9/24/86

Title: Quality Control Supervisor

Company Name: Resinold Engineering Corporation

Address: 3445 Howard Street

City: Skokie   State: IL   Zip Code: 60076

Telephone: (312) 673-1050

(Past) Asbestos products manufactured: Phenolic molding compounds

(Past) Approximate plant production capacity (for each asbestos-containing product):

Manufacturing products containing asbestos at present (Yes/No)? No

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

   Yes

3. Estimated time required to make conversion:

   6 months

4. Estimated cost of conversion:

   $30,000

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5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

10% slower production. New equipment would be no better.

6. Is equipment useable for another industry (Yes/No)? NA If Yes, please comment:

7. Can equipment be sold to foreign manufacturers (Yes/No)? No

8. Has equipment already been sold (Yes/No)? No

If Yes, please give name and address of purchaser

____

____

____

____

9. Estimated cost of equipment teardown/cleanup:

Included in conversion costs

10. Would it be possible to arrange a future PEI visit (Yes/No)? No

What is the procedure for obtaining permission to arrange a site visit?

Note: N/A = Not applicable
N.A. = Not available

EQUIPMENT DATA
EQUIPMENT WAS CONVERTED TO HANDLE ASBESTOS-FREE PRODUCTS

*Primary equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight (tons)[b]

[a] What would it cost to purchase this equipment new today (estimate)?
[b] Please indicate units if other than tons.

* Please include any handling/pollution control equipment (baghouse).

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PEI Survey/
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Written Comm N(2)-15 (39) File

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Supradur®

62036
N2-15 (39)

RECEIVED
OCT 15 1986
PEI ASSOCIATES, INC.
By_____________________

October 10, 1986

Mr. Yatendra M. Shah, P.E.
PEI Associates, Inc.
11499 Chester Road
Cincinnati, Ohio 45246

RE: EPA Contract No. 68-02-4248
PEI PN 3687-23

Dear Mr. Shah:

Enclosed is the OTS Survey Form requested in your letter of September 22, 1986.

Sincerely,
SUPRADUR MANUFACTURING CORPORATION

Alfred E. Netter
President

Encl.

AEN:lh

15-22a

OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Contact: Alfred E. Netter

Date: September 26, 1986

Title: President

Company Name: Supradur Mfg Corp.

Address: P. O. Box 908

City: Rye State: N.Y. Zip Code: 10580

Telephone: (914) 967-8230

Asbestos products manufactured: Roofing & Siding

Approximate plant production capacity (for each product): In 1985
134,800 squares (12,000 tons) siding and 40,000 squares (9,500 tons roofing

Manufacturing products containing asbestos at present (Yes/No)? Yes

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?
Extensive Research has not yet demonstrated that the (asbestos-containing) products made on our current machinery can be manufactured on the same machinery without using asbestos. The most likely course of action necessary in order to make non-asbestos-cement roofing and siding would be to construct an entirely new factory at a cost of $8 - 10 million.

3. Estimated time required to make conversion:

   In either case, mentioned in question 2 above, the time frame would be 12 - 24 months.

4. Estimated cost of conversion:

   If conversion of current facility is possible, it is estimated to cost $2 - 5 million.

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

Production rates are unknown as no machinery to make roofing and siding in a "dry-process" has yet to be invented.

6. Is equipment useable for another industry (Yes/No)? No ________ If Yes, please comment:

7. Can equipment be sold to foreign manufacturers (Yes/No)? No ________

8. Has equipment already been sold (Yes/No)? No ____________

If Yes, please give name and address of purchaser

____

____

____

____

9. Estimated cost of equipment teardown/cleanup:

Unknown

10. Would it be possible to arrange a future PEI visit (Yes/No)? ________

What is the procedure for obtaining permission to arrange a site visit?

Subject to an advance request, scheduling and purpose of the visit.

Note: N/A = Not applicable
N.A. = Not available

EQUIPMENT DATA
ASBESTOS-CEMENT SHEET AND SHINGLE
[FLAT SHEETS (INCLUDING SHINGLE)]

	Equipment item/area	Number	Age (yrs)	Remaining Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight[b] (tons)
Moody	~~Pan grinder~~ (for opening asbestos fiber bundles)	1	30	20				
	Batch mix	4	20	30				
	Stuff chest (continuous slurry supply)	1	20	30				
	Sheet machine (with vacuum pumps)	1	20-30	20				
Punch Press	~~Stamping machine~~ (for final cut of wet sheet)	5	10-20	15				
	Stack press	0						
Autoclave	~~Sheet curing~~	4	25	10	UNKNOWN			
	Other Brushers	1	10	20				
	Other Waxers	1	15	15				
	Other Paint Machine	1	15	15				
	Other							
	Other							

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

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62036
N_2-15(40)

OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Contact: Ms. Anne Willard Date: 9/22/86

Title: Technical Director

Company Name: Sterling-Clark-Lurton Corp.

Address: 184 Commercial Street

City: Malden State: MA Zip Code: 02148

Telephone: (617) 322-0163

Asbestos products manufactured: Sash/glazing sealant compounds

Approximate plant production capacity (for each product): *40,000 gal/yr

Manufacturing products containing asbestos at present (Yes/No)? Yes

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

   Yes - currently manufacture other non-asbestos-containing calk compounds.

3. Estimated time required to make conversion:

   Equipment - none However, conversion (i.e., finding new raw material) is very labor-intensive/time-consuming process (i.e., laboratory testing of new product).

4. Estimated cost of conversion:

   Equipment - none Labor - hard to estimate

* ¼ time they manufacture asbestos calk - use 100 lb asbestos/batch

120 gal (2 batches/day) 4 days/wk work {1 shift/day
250 gal (2 batches/day) 52 wk/yr {9 h/day

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

Production is decreased due to added mixing time -- operators must on occasion break up lumps manually.

6. Is equipment useable for another industry (Yes/No)? Yes If Yes, please comment:

Any paste-type industry could use mixers.

7. Can equipment be sold to foreign manufacturers (Yes/No)? No

Shipping costs would make it prohibitive.

8. Has equipment already been sold (Yes/No)? No

If Yes, please give name and address of purchaser

9. Estimated cost of equipment teardown/cleanup:

18 labor hours for teardown/cleanup to remove mixer.

10. Would it be possible to arrange a future PEI visit (Yes/No)? Yes

What is the procedure for obtaining permission to arrange a site visit?

Ms. Anne Willard or Joe Parker (Plant Manager)

Note: N/A = Not applicable
N.A. = Not available

EQUIPMENT DATA
ASBESTOS SEALANTS

Primary equipment item/area	Number	Age (yrs)	Remaining useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight (tons)[b]
Mixer (120-gal, 250-gal)	2	25	5	Unknown	Unknown	Unknown	Unknown
Twin screw conveyor (filling machine)	2	15	15	Unknown	Unknown	Unknown	Unknown
Hoods	2	20	Indefinite	Unknown	Unknown	Unknown	Unknown
Dust collector	1	20	Indefinite	Unknown	Unknown	Unknown	Unknown

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

EQUIPMENT DATA
ASBESTOS SEALANTS

Primary equipment item/area	Number	Age (yrs)	Useful life (yrs) Remaining	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight (tons)[b]
Mixer (120-gal, 250-gal)	2	25	5	Unknown	Unknown	Unknown	Unknown
Twin screw conveyor (filling machine)	2	15	15	Unknown	Unknown	Unknown	Unknown
Hoods	2	20	Indefinite	Unknown	Unknown	Unknown	Unknown
Dust collector	1	20	Indefinite	Unknown	Unknown	Unknown	Unknown

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

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N_2-15 (41)

OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Contact: Mr. Richard Wheeler   Date: 9/25/86

Title: Plant Manager

Company Name: Thermoset Plastics, Inc.

Address: 5101 East 65th Street

City: Indianapolis   State: IN   Zip Code: 46220

Telephone: 317/259-4161

Asbestos products manufactured:[a] Liquid plastics

Approximate plant production capacity (for each product):[b] Estimated to be 200,000 lbs/yr or approximately 20,000 gallons/yr

Manufacturing products containing asbestos at present (Yes/No)? No

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

   Yes. Asbestos raw material replaced with substitutes in some 20-30 formulas.

3. Estimated time required to make conversion:

   None. Same equipment used.

4. Estimated cost of conversion:

   No increased equipment or raw material costs (i.e., asbestos only 2% of product price versus 5% for substitutes).

[a] Stopped using asbestos approximately 3 years ago.

[b] June 1985-June 1986 ran 2079 batches; 1918 regular runs at 2100 lbs (210 gallons) average per batch and 161 bulk runs at 5431 lbs avg. per batch; 1/20th of all regular runs contained asbestos; no asbestos was ever used to make bulk runs.

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

   Mixing time increased due to poor dispersion properties of substitutes and other formulas may require that heat be added increasing their batch time by 2 to 3 hours. Final products are also not as stable (i.e., lower shelf life). Must now keep smaller inventory (i.e., 1 month for substitues versus 6 months with asbestos).

6. Is equipment useable for another industry (Yes/No)? ___Yes___ If Yes, please comment:

   Plastics or paint industry

7. Can equipment be sold to foreign manufacturers (Yes/No)? ___N/A___

8. Has equipment already been sold (Yes/No)? ___N/A___

   If Yes, please give name and address of purchaser

   ____

   ____

   ____

   ____

9. Estimated cost of equipment teardown/cleanup:

   Minimal - 2 men for 1 day at $25/h (with overheads) or approximately $400.

10. Would it be possible to arrange a future PEI visit (Yes/No)? ___Yes___

    What is the procedure for obtaining permission to arrange a site visit?

    Mr. Richard Wheeler

Note: N/A = Not applicable
N.A. = Not available

EQUIPMENT DATA
ASBESTOS GASKETS/PACKINGS

Primary equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight (tons)[b]
*High speed mixer	3	10-12	8	$10,000-$25,000	$2000-$5000	NA	NA

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

*No other process equipment; raw materials added manually and product is poured directly from tank; mixing operations are done under hoods which are vented directly to the air (i.e., no baghouse is used).

1520

PEI Survey/
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62036
N2-15(42)

OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Contact: Skip Carroll Date: 10/14/86

Title: Vice President

Company Name: U.S. Automotive Manufacturing

Address: Airport Road

City: Tappahannock State: Virginia Zip Code: 22560

Telephone: (804) 443-4327

Asbestos products manufactured: Light & medium duty vehicle disc brake pads and drum linings.

Approximate plant production capacity (for each product): Brake shoe linings: $10x10^6$ pieces/yr; disc pad friction material: $4x10^6$ pieces/yr.

Manufacturing products containing asbestos at present (Yes/No)? Yes (65% asbestos based products)

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

   The machinery itself can be used without modifications. However, the metallic asbestos substitute materials require new dies and tooling. The components actually cost more than the machines themselves. If an acceptable organic asbestos substitute were developed there would be a minor equipment modification strategy required.

3. Estimated time required to make conversion:

   To make the changes implemented so far required a lead time of 10-15 weeks. Should the regulations require a complete change over there will be a hold up in tool and die manufacturing companies. It will take a few years for these companies to get up to speed.

4. Estimated cost of conversion:

The company has been experimenting with an organic asbestos substitute product that would cost 75 to 80% of metallic based product manufacturing. The metallic product manufacturing cost is about 3 times the cost of manufacturing the asbestos-containing products. At the current level of capacity, the cost to convert to 100% metallic based products would be roughly $1 mm. To convert to a combination metallic & non-asbestos organic friction product would be roughly $1.2 to 1.5 mm.

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

N.A.

6. Is equipment useable for another industry (Yes/No)? No* If Yes, please comment:

7. Can equipment be sold to foreign manufacturers (Yes/No)? No

8. Has equipment already been sold (Yes/No)? No

If Yes, please give name and address of purchaser

N/A

9. Estimated cost of equipment teardown/cleanup:

Uncertain - would be considerably more than $100,000.

10. Would it be possible to arrange a future PEI visit (Yes/No)? Yes

What is the procedure for obtaining permission to arrange a site visit?

Suggested potential plant site visits representative of after market manufacturers:

Company	Location
Certified Brake	Danville, KY
Nuturn Corp.	Smithville, TN
Abex	Winchester, VA
US Automobile Mfg.	Tappahannock, VA
Virginia Friction Products	Walkerton, VA
Krasne (now HKM of California)	LosAngeles, CA
Wagner's Guardian Div.	Brighton, MA
Bendix	Jefferson, TN

Note: N/A = Not applicable
N.A. = Not available

* i.e., 90% of the equipment - very industry specific.

EQUIPMENT DATA
ASBESTOS FRICTION MATERIALS

Equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)**	Equipment weight (tons)[b]
Mixer	4	10-20	7-15				N.A.
Preform compression molding machines	3	5-10	10+				N.A.
Heated compression molding machines	-	-	-				N.A.
Combination slitter and cutter	-	-	-				N.A.
Arc-forming molding machine	-	-	-				N.A.
Curing oven	2	12-15	~5				N.A.
Finishing equipment (drills)	12	5-15	5-10				N.A.
Finishing equipment (grinders)	4	10	5-10				N.A.
Other Hot presses	1*	5-10	40 (min)				N.A.
Other							
Other							
Other							
Other							
Total/Average				$2mm	<$350K (Assuming facility liquidation)		

---

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

* This is a large unit - a typical installation would have 2 smaller units to total this capacity.

** Questionable whether scrap value would be enough even to cover cost of hauling material away.

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N_2-15(43)

OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Contact: Dewey Long Date: 9/23/86

Title: Company Attorney

Company Name: Virginia Friction Products

Address: P.O. Box 87

City: Houston State: Texas Zip Code: 77001

Telephone: (713) 994-3160

Asbestos products manufactured: Asbestos friction materials & asbestos gaskets for oil drilling rigs and large off road vehicles such as giant cranes.

Approximate plant production capacity (for each product): N.A.

Manufacturing products containing asbestos at present (Yes/No)? Yes

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

   No substitutes for their products yet. They've been looking.

3. Estimated time required to make conversion:

   N.A.

4. Estimated cost of conversion:

   Have searched extensively for asbestos substitutes and none have proven acceptable. D.C. Long said the company will probably be forced to close down if asbestos cannot be used in the future.

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

N/A

6. Is equipment useable for another industry (Yes/No)? __No__ if Yes, please comment:

7. Can equipment be sold to foreign manufacturers (Yes/No)? __N.A__

8. Has equipment already been sold (Yes/No)? __No__

If Yes, please give name and address of purchaser

N/A

9. Estimated cost of equipment teardown/cleanup:

N.A.

10. Would it be possible to arrange a future PEI visit (Yes/No)? __Possible__

What is the procedure for obtaining permission to arrange a site visit?

Note: N/A = Not applicable
N.A. = Not available

EQUIPMENT DATA
ASBESTOS FRICTION MATERIALS
- N.A.* -

Equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight (tons)[b]
Mixer							
Preform compression molding machines							
Heated compression molding machines							
Combination slitter and cutter							
Arc-forming molding machine							
Curing oven							
Finishing equipment (drills, grinders, etc.)							
Other							
Other							
Other							
Other							
Other							

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

* Dewey Long reported that the company is short handed as a result of layoffs. The slump in the oil industry has hurt the company's business. Long said if at some point in the future we feel the information is critical he would try to get it again from the plant foreman.

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PEI Survey/
OPTS 62036 Asbestos Ban
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62036
N2-15(44)

EPA/OTS
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OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Contact: Marvin Sylva Date: 10/13/86

Title: General Plant Manager

Company Name: Virginia Friction Products

Address: Route 634

City: Walkerton State: Virginia Zip Code: 23177

Telephone: (804) 769-3511

Asbestos products manufactured: Light & medium duty vehicle disc brake pads and drum linings.

Approximate plant production capacity (for each product): N.A.

Manufacturing products containing asbestos at present (Yes/No)? Yes

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

   Some equipment can be modified. However, Virginia Friction Products is acquiring other equipment for use with asbestos substitutes.

3. Estimated time required to make conversion:

   A great deal of time is required to develop the asbestos substitute products and processes themselves. The development process requires many trial and error iterations. Equipment conversion times where applicable are minimal.

4. Estimated cost of conversion:

   The conversion cost is minor in comparison to the cost of production time loss. For example, a drum liner production line dropped from 58 ft/min to 23 ft/min. The production cost for a $.20 item made with asbestos is about $.60-$.80 using asbestos substitutes. Sylva reported that if Virginia Friction Products moved to 100% asbestos substitutes it could not compete in the current market. If imports of asbestos based products were not prohibited, the company would probably go out of business.

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

   Production capacity drops significantly when switching to asbestos substitutes (see item 4).

6. Is equipment useable for another industry (Yes/No)? No if Yes, please comment:

7. Can equipment be sold to foreign manufacturers (Yes/No)? Yes (possible canadian or overseas market).

8. Has equipment already been sold (Yes/No)? No

   If Yes, please give name and address of purchaser

   N/A

9. Estimated cost of equipment teardown/cleanup:

   N.A.

10. Would it be possible to arrange a future PEI visit (Yes/No)? Yes

    What is the procedure for obtaining permission to arrange a site visit?

Note: N/A = Not applicable
N.A. = Not available

EQUIPMENT DATA
ASBESTOS FRICTION MATERIALS

Equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value[i] ($)	Scrap value ($)	Equipment weight[b,j] (tons)
Mixer	3	<9	>20	25-35K	15K	N.A.	N.A.
Preform compression molding	1[c,d]	<9	>20	214K	109K	N.A.	N.A.
machines	8[e]	<9	>20	360K	184K	N.A.	14
Heated compression molding	1[d]	<9	>20	150K-180K	84K	N.A.	N.A.
machines	6[e]	<9	>20			N.A.	N.A.
Combination slitter and cutter	5	<9	>20	20K	10K	N.A.	N.A.
Arc-forming molding machine	2	<9	>20	14-16K	8K	N.A.	N.A.
Curing oven	1[f]	<9	>20	60K	31K	N.A.	N.A.
Finishing equipment (drills,	9	<9	>20	85K	43K	N.A.	N.A.
grinders, etc.)	4[g]	<9	>20	40K[j]	20K	N.A.	N.A.
Other							
Other							
Other							
Other							
Other							

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

[c] Rolling type for drums.

[d] This is a large unit; difficult conversion.

[e] Easy conversion.

[f] Large unit - 24,000 ft² capacity.

[g] 2 big and 2 small units. The larger units are $15,000 each. The smaller units each cost about $5,000.

[h] $45,000 each.

[i] Estimated at just over 50% of cost.

[j] Most equipment weighs anywhere from 1500 lbs to 3-4,000 lbs.

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62036
N2-15(45

OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Contact: Michael Rabren Date: 9/23/86

Title: Technical Director

Company Name: U.S. Cylinders Div. of WERCo, Inc.

Address: 100 Industrial Park, Joy Street

City: Citronelle State: Alabama Zip Code: 36522

Telephone: (205) 866-5523

Asbestos products manufactured: Compressed Gas Cylinders (acetylene).

Approximate plant production capacity (for each product): 12,000 Cylinders/month.

Manufacturing products containing asbestos at present (Yes/No)? Yes

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

   Rabren reported that there are no asbestos substitutes available for this product.

3. Estimated time required to make conversion:

   N/A

4. Estimated cost of conversion:

   N/A

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

N/A

6. Is equipment useable for another industry (Yes/No)? No if Yes, please comment:

There are only about 6 facilities in the world (3 in U.S.) making these tanks. The equipment is very specialized and would not be useful for other processes. It is doubtful that even the company's competitors could use the equipment since each company has its own manufacturing process.

7. Can equipment be sold to foreign manufacturers (Yes/No)? No

Every system is different.

8. Has equipment already been sold (Yes/No)? No

If Yes, please give name and address of purchaser

N/A

9. Estimated cost of equipment teardown/cleanup:

50,000

10. Would it be possible to arrange a future PEI visit (Yes/No)? Yes (but not EPA).

What is the procedure for obtaining permission to arrange a site visit?

Note: N/A = Not applicable
N.A. = Not available

EQUIPMENT DATA
ASBESTOS COMPRESSED GAS CYLINDER MANUFACTURING

Equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight (tons)[b]
Mixers	4	<10	15-20				N.A.
Holding Vessels	4-5	<10	15-20				N.A.
Autoclaves	3	<10	15-20				N.A.
Ovens	4	<10	15-20				N.A.
SS-Slurry Curing/mix	N.A.	<10	15-20				N.A.
Pumps and Motors	N.A.	<10	15-20				N.A.
				$250K (total)	$50K (total)	<$50K (total)	

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

1530

PEI Survey/
OPTS 62036 Asbestos Ban
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62036
N2-15(46)

OTS SURVEY FORM
ASBESTOS PRODUCTS MANUFACTURERS

Contact: Greg Beckett Date: 9/23/86

Title: Plant Manager

Company Name: Wheeling Brake Block Manufacturing

Address: 56100 Berkley Avenue

City: Bridgeport State: CT Zip Code: 43912

Telephone: (304) 232-7460

Asbestos products manufactured: Brake blocks, drum brake linings & friction materials for heavy duty vehicles - cranes, bull dozers, trucks, etc.

Approximate plant production capacity (for each product): N.A.

Manufacturing products containing asbestos at present (Yes/No)? Yes*

EQUIPMENT DATA

1. Please complete the attached equipment data table(s).

2. Can the equipment used to manufacture these products be converted for use with asbestos substitute materials (i.e., same product different material)?

   Yes - basically the same equipment with some modifications. Some equipment requires replacements. Used carbide saw blades on asbestos products - have had to switch to diamond. The asbestos substitute materials are significantly more abrasive. Grinding stones are now replaced monthly - they used to last a year.

3. Estimated time required to make conversion:

   N.A. - (major operation changes were made; no details were given with respect to time requirements)

4. Estimated cost of conversion:

   N.A. - (Basically the same equipment but less through put)

* 95% converted to asbestos substitutes.

5. Equipment operating rate after conversion -- How is productivity affected by conversion? How would this converted equipment compare with equipment specifically designed for the asbestos substitute products.

   1/3 reduction in production resulted from conversion to asbestos substitutes. Procedures take longer & cycling is slower. Costs have doubled. It takes 33% more time to make the same product and the raw materials are more expensive.

6. Is equipment useable for another industry (Yes/No)? ___No___ If Yes, please comment:

7. Can equipment be sold to foreign manufacturers (Yes/No)? ___N.A.___

8. Has equipment already been sold (Yes/No)? ___No___

   If Yes, please give name and address of purchaser

   ___N/A___

9. Estimated cost of equipment teardown/cleanup:

   N.A.

10. Would it be possible to arrange a future PEI visit (Yes/No)? ___No___

    What is the procedure for obtaining permission to arrange a site visit?

    Beckett said that Lee Burgess, the owner, would probably be reluctant to permit a plant visit by PEI personnel.

Note: N/A = Not applicable
N.A. = Not available

EQUIPMENT DATA
ASBESTOS FRICTION MATERIALS

Equipment item/area	Number	Age (yrs)	Useful life (yrs)	Cost for same equipment today ($)[a]	Resale value ($)	Scrap value ($)	Equipment weight (tons)[b]
Mixer	1	>25	N.A.	N.A.	N.A.	N.A.	N.A.
Preform compression molding machines							
Heated compression molding machines	12	>25	N.A.	N.A	N.A.	N.A.	N.A.
Combination slitter and cutter	4	>25	N.A.	N.A	N.A.	N.A.	N.A.
Arc-forming molding machine	4	>25	N.A.	N.A	N.A.	N.A.	N.A.
Curing oven	3		N.A.	N.A	N.A.	N.A.	N.A.
Finishing equipment (drills)	6	8-10	N.A.	N.A	N.A.	N.A.	N.A.
Finishing equipment (grinders)	6	>25	N.A.	N.A	N.A.	N.A.	N.A.
Other Saws	5	8-10	N.A.	N.A	N.A.	N.A.	N.A.
Other							
Other							
Other							
Other							

[a] What would it cost to purchase this equipment new today (estimate)?

[b] Please indicate units if other than tons.

TSCA PHONE CALL LOG*

RIA 398
421
487
LOG 2244

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62036
B_6-398

Project: Asbestos

Name of ICF Caller: Rick Hollander

Organization Contacted: Saab-Scania

Location: Orange, CT

Name of Person Contacted: David Rainey

Position of Person Contacted: Environmental Activity Supervisor

Phone Number: 203-795-5671

Date/Time of Contact: 4/21/86 4pm.

Questions/Responses:

Asked about 1985 production of asbestos disc brake pads LMV and clutch facings.

They no longer use asbestos, their cars have all non-asbestos disc brakes

They stopped importing asbestos clutch facings into the US. prior to 1985.

1985 imports = Ø for asbestos clutch facings and asbestos disc brake pads LMV.

398
421

2244

*To be maintained in permanent file.

ICF INCORPORATED

62036
B6-401

Project: Asbestos

Name of ICF Caller: Rick Hollander

Organization Contacted: Guardian/Wagner (called Wagner in reports)

Location: (see company comments)

Name of Person Contacted: Frank Hayes

Position of Person Contacted: ~~[illegible]~~ VP

Phone Number: 201-386-9300

Date/Time of Contact: 12/5/86, 3:15 PM

RTA 401 432

LOG 2245

Questions/Responses:

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1985 imports of asbestos-based products?

drum brake linings	disc brake pads (LMV)	brake blocks
95% of 16,000,000 pieces	4,500,000 pieces	5% of 16,000,000 pieces

Gaurdian Division is part of Wagner.
Guardian Corporation has been bought out by Wagner.

401
RTA 432

2245

*To be maintained in permanent file.

ICF INCORPORATED

62036
B_6-448

RIA ~~448~~

LOG 2252

Project: Asbestos resurvey

Name of ICF Caller: Mike Oeschwind

Organization Contacted: Allied Automotive / Bendix

Location: Troy NY

Name of Person Contacted: Bob Bush

Position of Person Contacted: Marketing Salesman

Phone Number: 518-273-6550

Date/Time of Contact: 7/10/87 9am

Questions/Responses: Q: What is the price of full metallic brake block and its longevity. Also this info relative to the asbestos brake block. Bob Bush Spoke w/ secretary

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They sell full-metallic

cost is significantly higher than the asbestos

4515 common block

blue sheet price for 100% metallic = \$133.60 = \$80.16 per set (8 pieces) \$16.70 or \$10.02 /piece

Blue set price
Asbestos Product
3 different grades

Premium grade \$73.08 = \$43.85 per set or \$5.48 per piece

medium \$59.68 = \$35.81 per set or \$4.48 per piece

Standard 36.54 = \$21.92 per set or \$2.70 /piece

Take 40% off of these prices because they are not real prices. The real prices are in red

Severe duty = up to double the life over the asbestos w/ their metallic.

They feel they have the best product

The reason for the difference in price is their product is better.

RIA 448

2252

*To be maintained in permanent file. Remember.

ICF INCORPORATED

Project: asbestos Rewrite of Appendix A

62036

Name of ICF Caller: Mike Geschwind

Organization Contacted: (Motion Control Industries Division of Carlisle

B6-452

Location: Ridgeway PA

Name of Person Contacted: Bob Tami

BEST COPY AVAILABLE

RIA 452

Position of Person Contacted:

LOG 2251

Phone Number: 814-773-3185

Date/Time of Contact: 7/10/87 10 pm

Questions/Responses: Questions about Full-metallic Brake Blocks

Longevity - lasts about the same amount of time

Cost 25% more than asbestos

RIA452

Full metallic lasts as long as asbestos in the same application. However it will be about 25% more expensive than the asbestos product - for the same application

Problem with heavy applications is that it is difficult to get the steel very hard or hard enough.

They don't make this product. They feel that the other products will eventually be developed to take over the super heavy applications (eg. NAO's w/mineral fiber and other fibers)

2251

NAO's will be more expensive initially but because they last longer, they'll be cheaper than asbestos in the long run

They are getting rid of asbestos (or may have already done so for this application) and just make NAO's.

*To be maintained in permanent file.

ICF INCORPORATED

TSCA PHONE CALL LOG*

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6

62036
06-457

Project: Asbestos

Name of ICF Caller: [redacted] Rick Hollander

Organization Contacted: Freightliner Corp. (Mercedes Truck Co. of North America)

Location: Portland, OR

Name of Person Contacted: Tom Robinson

RIA 457 / 476

Position of Person Contacted: Executive Engineer

Phone Number: 503-283-8063

LOG 2253

Date/Time of Contact: 11/26/86

Questions/Responses:

Called to find imports of brake blocks and clutch facings made from asbestos in 1985.

RIA
~~425~~
476
457

For the ~~the~~ aftermarket, Freightliner imported

756 x 2 = 1512 brake blocks

and 820 clutch facings

For OEM Freightliner imported

5,037 clutch facings

5,037 x 4 x 2 = 40,296 brake blocks.

Therefore total OEM + aftermarket imports of asbestos products ~~are~~ in 1985

clutch facings = 5,857
brake blocks = 41,808

2253

*To be maintained in permanent file.

ICF INCORPORATED

62036
NON-CBI

Project:* Asbestos

Name of ICF Caller: Rick Hollander

Organization Contacted: Friction Products

Location: Medina, OH

Name of Person Contacted: Dan Cramer

Position of Person Contacted: Purchasing Agent

Phone Number: 216-725-4941

Date/Time of Contact: 10/9/86, 4:30 PM

B-457

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Questions/Responses:

Friction Products makes only nonasbestos brake blocks for heavy equipment, trucks + aircraft. They make a semi-metallic (~~...~~ also called full-metallic block) block for these mkts. All of their blocks are custom-made for the job.

2314

These "semi-metallic" blocks are:

RIA USE

- 2-3 times longer service life over asbestos
- @ $30 / block (a representative price for a heavy truck block)
- 100% substitutable w/ asbestos blocks

The higher purchase cost is overcome by longevity ~~...~~ and performance of this block over the asbestos block. These semi-met blocks good for extreme high temperature ranges -- e.g., aircraft brake blocks.

*To be maintained in permanent file.

ICF INCORPORATED

TSCA PHONE CALL LOG*

NON-CBI MG

62036

B6-472

Project: Asbestos Use + Substitutes Analysis

Name of ICF Caller: Rick Hollander

Organization Contacted: ~~John~~ Deere + Co. (John Deere)

Location:

Name of Person Contacted: Ralph Grotelueschen

Position of Person Contacted: Director Safety, Standards Environment + Energy Mngment.

Phone Number: 309-752-5151

BEST COPY AVAILABLE

Date/Time of Contact: 10/30/86 4:30pm

Questions/Responses:

Deere + Co ~~...~~ is now using non-asbestos products of Raymark + Borg-Warner for their machinery. (Thus Deere should now what kind of brake blocks Raymark is making).

RIA 472
493
505
LOG 2256

RIA 472

- Important to match friction coefficient ~~for~~ the aftermarket - the problem is really here + not in OEM. Deere & Co. created a task force to see if possible to develop substitutes for replacements. Problem is that ~~there~~ isn't a large enough replacement market to have incentive to find substitutes. Thus ~~they~~ don't put R&D dollars into replacements.

- But in new system, they change the brake system ~~design~~ to meet the different coefficients of friction of substitutes to achieve same level of performance (in terms of noise, grab etc...)

2256

Kevlar w/ carbon + fiberglass fibers used for brake blocks and possibly clutch facings

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ICF INCORPORATED

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* John Deere is 50% non-asbestos in brake linings and automatic transmission components

Brake linings:

fiberglass
graphite
wollastonite
Kevlar
} He's confident that no one will work. Need combination of fibers and fillers. Couldn't be more specific. Too many properties to manage.

Ceramic -- less so than the others

fiberglass used for wet brake blocks (oil flows over everything; brake blocks are dry) in agricultural tractors (This would fall under friction materials. These brake systems are unique to agricultural tractors.

Automatic Transmission Components (discs - wet transmission)

Consider the above fibers as well as cellulose based components

Raymark
Borg Warner
SK Wellman
} are the suppliers

(These fall under friction materials - these transmissions unique to agricultural tractors)

Clutch Facings - for 15 speed automatic transmission agricultural tractor (newly engineered)

Substitutes:

- cotton fiber/carbon fiber w/ cellulose, phenolic resin and graphite filler

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- cellulose fiber w/ cellulite and phenolic resin.

all of the above are made by Raymark, Borg-Warner, and SK Wellman.

To use the substitutes the transmission system was totally re-engineered. Could interchange with asbestos ~~tran~~ automatic transmission components. Extremely difficult to develop substitutes w/o re-engineering the transmission or brake system.

For the 15 speed transmission it probably took 6 years to develop and test.

Despite the above substitutes, for wet brake linings for tractors Kevlar + fiberglass combinations will be most likely substitute taking a majority of market share.

Service life these transmission parts is life of tractor because it is too expensive to service. They have the same service life of asbestos.

TSCA PHONE CALL LOG*

Project: Asbestos

NON-CBI MG

Name of ICF Caller: Rick Hollander

Organization Contacted: Borg ~~Warner~~ BEST COPY AVAILABLE

62036

Location:

B6-492

Name of Person Contacted: Thomas Longtin

Position of Person Contacted:

Phone Number: 815-469-2721

Date/Time of Contact: 11/20/86

automatic transmission

Questions/Responses:

RIA 492

1) any other substitute than cellulose/cotton → yes → 2 + mkt. share switch-over

life of the product same as asbestos, but product (25% more expensive than asbestos)

→ 1/2 replaced now by cellulose/cotton fiber, given another 5-10 yrs would 100% replaced (w/out any regulation)

2) any idea of size of asbestos auto tran components mkt?
✓ - particularly in LMV (largest segment?)
✓ - any idea of trends in this mkt?

Mkt. Being rapidly replaced by cellulose/cotton fiber. → Borg-Warner is the leader in this substitution

These firms may make asbestos automatic transmission friction components

✓ - American Friction Materials (Detroit, MI) Art Steffanutti → (313) no listing in Detroit!
✓ - Raymark
✓ - Luk (Tenn. or KY?)
✓ - Daiken (Japanese importer)

Interchangeable with aftermarket w/o loss of performance

RIA 492
LOG 2260

RIA 492

62036
B6 ______ file

2260 ✓

*To be maintained in permanent file.

ICF INCORPORATED

roject: Asbestos

lame of ICF Caller: Rick Hollander

)rganization Contacted: Mead Corp.

ocation: Dayton, OH

lame of Person Contacted: L. McDonnold

osition of Person Contacted: Vice Pres. ?

hone Number: 513-439-9230

)ate/Time of Contact: Dec. 15, 1986

Non-CBI
MG

62036
B6-500

62036
B6 file

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uestions/Responses:

automatic transmission components include the friction clutch plates + lining for the transmission band. Mead produces non-asbestos friction paper to producers of automatic transmission friction components. Mead discontinued production of asbestos-based paper in December 1983. Almost all friction paper for auto. trans. components is cellulose-based. Nearly 100% of market is already cellulose-based.

2259

RIA 500

RIA 500

LOG 2259

*To be maintained in permanent file.

ICF INCORPORATED

Raymark
CORPORATION

100 OAKVIEW DRIVE, TRUMBULL, CONNECTICUT 06611 (203) 371-0101

OPTS Docket # 62036 Asbestos Ban
R/P E 102a File

EPA
INFO. CONTROL

1986 APR -2 PM 8:28 APR -3 9:22

62036
E102a

March 26, 1986

Document Control Officer (TS-793)
Office of Toxic Substances
Environmental Protection Agency
Room E-209
401 M Street, N.W.
Washington, D.C. 20460

Dear Sir:

Subject: OPTS-62036

Raymark Industries, a manufacturer of asbestos-containing industrial friction materials and asbestos-containing reinforced plastics essential to national defense missile and aircraft programs, requests the opportunity to participate in informal hearings, scheduled to begin approximately May 14, 1986, concerning the EPA proposed asbestos Rule published in the Federal Register, January 29, 1986.

Respectfully submitted,

John H. Marsh

John H. Marsh

JHM:mar

6 2036
E 8

COMPANY SANITIZED

Arent, Fox, Kintner, Plotkin & Kahn

Washington Square
1050 Connecticut Avenue, N.W.
Washington, D.C. 20036-5339

63-8600155

Writer's Direct Dial Number
(202) 857-6087

EPA
INFO. CONTROL BRANCH
1986 JUN 13 AM 11:03

June 12, 1986

Ms. Michelle Zenon
OTS Document Control Officer (TS-793)
Environmental Protection Agency
Room 220, East Tower - Waterside Mall
401 M Street, S.W.
Washington, D.C. 20460

ARENT, FOX, KINTNER, PLOTKIN & KAHN
FOR ABEX CORP

Re: OPTS-62036

OPTS Docket # 62036 Asbestos Ban File
M/C E 8

Dear Ms. Zenon:

As discussed, I am submitting to the EPA Document Receipt Station at the OTS Document Control Office three sets of the comment of my client Abex Corporation in the above-referenced docket, for placement in the public record (these documents contain no confidentiality markings, but carry indications of deletions of confidential material from the public record submission). In addition, I am submitting three sets of the confidential, proprietary version of the Abex comment which contains, at Charts B, C, D and E, competitively sensitive data of a trade secret nature which the company specifically requests be withheld from the public record, in accordance with the procedure outlined in the notice of proposed rulemaking at 51 Fed. Reg. 3738 (Jan. 29, 1986).

Abex requests the written assurance of EPA that the referenced confidential materials will be withheld from the public record pursuant to the Freedom of Information Act and Trade Secrets Act.

Sincerely,

Lawrence F. Henneberger

1149

Enclosures
(3 sets nonconfidential comment submission of Abex Corp.
3 sets confidential version of Abex Corp. comments)
cc: A. M. Unger, Esquire

Telephone: (202) 857-6000 Cable: ARFOX Telex: WU 892672 ITT 440266 Telecopier: (202) 857-6395

ARENT FOR ABEX CORP

OPTS Docket # 62036 Asbestos Ban
M/C E __________ File

COMPANY SANITIZED

RESPONSE OF ABEX CORPORATION TO
PROPOSED U.S. ENVIRONMENTAL PROTECTION
ADMNISTRATION RULE PROPOSAL OF
JANUARY 23, 1986

Abex Corporation
6 Landmark Square
P.O. Box 10268
Stamford, CT 06904-2268

June 1, 1986

INDEX

I. Statement by Abex Corporation

Abex Corporation, ("Abex"), a significant manufacturer through its Friction Products Division of braking friction materials for the motor vehicle, industrial machinery, and off-highway equipment industries, submits this statement and accompanying materials in response to the invitation for comments to the proposed rule announced by the U.S. Environmental Protection Administration on January 23, 1986 calling for, among other things, a phase-out of all uses of asbestos in friction materials under options ranging from five to ten years after promulgation of the rule.

As the keynote of its response, Abex states herein that it fully supports a phase-out of asbestos. On the basis of certain assumptions concerning future plans of original equipment manufacturers (see Chart D, infra), Abex contemplates that it will have ceased selling practically all friction materials containing asbestos by the end of 1989. Moreover, Abex stands ready to complete its phase-out even sooner, although any such acceleration depends chiefly on the concomitant ability of original equipment customers to convert to asbestos-free products for their near-term friction material requirements.

II. Abex's Manufacturing History of Asbestos-Free Friction Material

On the basis of its manufacture of asbestos-free friction materials commencing more than 30 years ago and continuing to the present, Abex has satisfied itself that such friction materials have demonstrated a successful capability and fitness for use for practically all automotive and truck braking applications. Abex began manufacturing asbestos-free materials approximately in the mid-1950's with its development of powdered metals for U.S. aircraft and industrial markets, continued such manufacture in the 1960-1970 decade with its development of resin-bonded metallic drum brake segments and semi-metallic disc pads, and progressed in the ensuing decade to the development of heavy-duty drum brake segments and blocks based on the use of fiberglass. Most other major brake lining manufacturers did not begin to place emphasis on developing asbestos substitutes until the mid-1970's. Concurrent with Abex's domestic development of asbestos substitutes, Abex's foreign affiliates were testing and developing other varieties of asbestos-free products for original equipment manufacturers like Volkswagen and Ford Europe. In 1981, Abex began selling its asbestos-free lining for the domestic school bus market, and it currently offers and sells this lining, in the form of three product lines, for practically all heavy-duty truck applications. Further, Abex has in the past three years made available and sold asbestos-free disc pads and drum brake segments for light truck and passenger car applications.

III. Abex's Declining Use of Asbestos

Charts A and B appended hereto illustrate Abex's decrease in the manufacture and sale of friction materials containing asbestos. Referring to chart A, Abex expects that the rate of sales conversion to non-asbestos materials will accelerate even faster in the next three-year period, so that by the end of 1988 its percentage of asbestos-free sales will have reached almost 100%. Chart B - prepared on the basis of declining asbestos purchases by Abex - makes essentially the same point as Chart A but in a different context.

CHART A

PERCENT OF ASBESTOS-FREE SALES

QUARTERLY

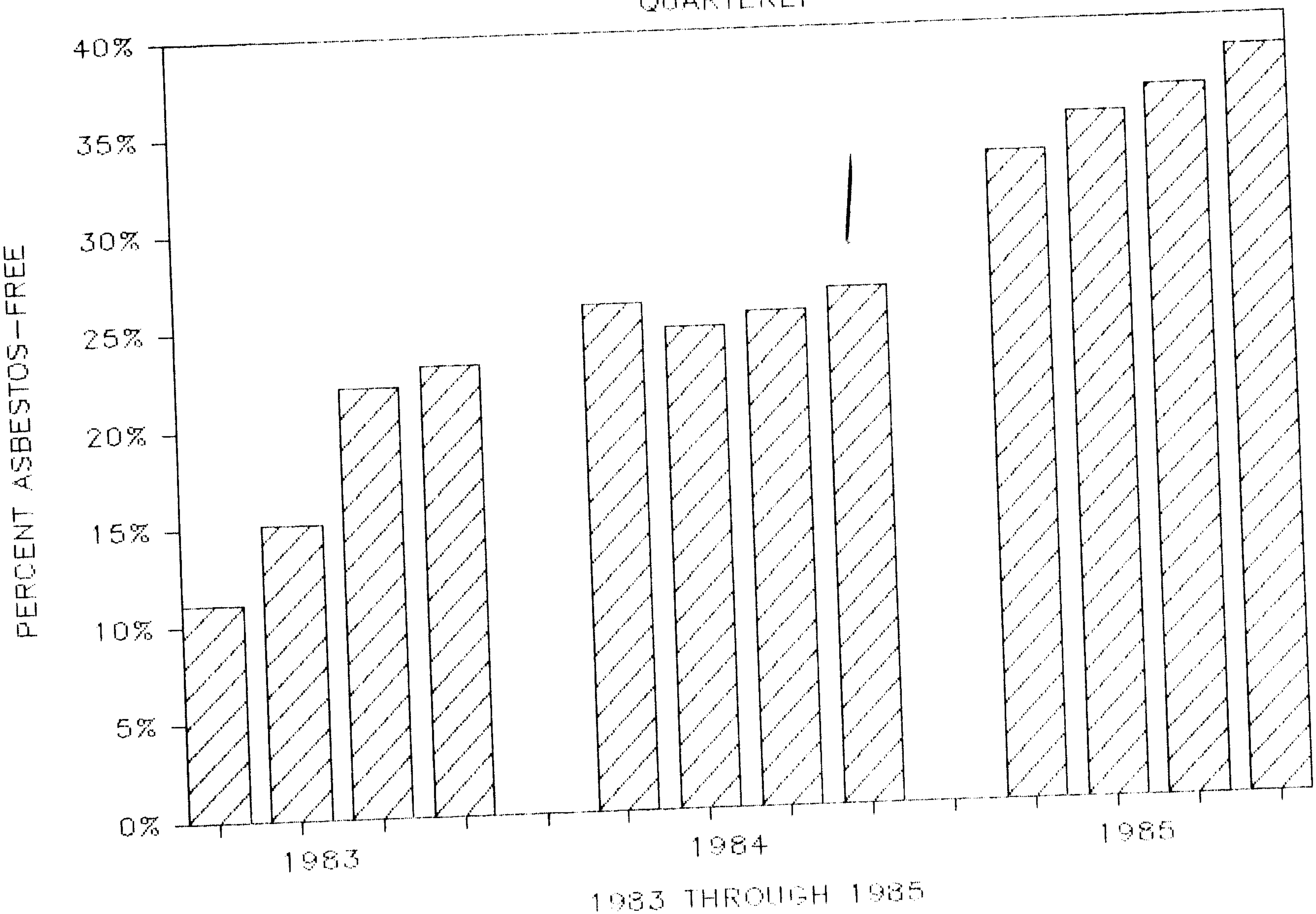

CHART B

ASBESTOS FIBER CONTENT

FPD—U.S. (WINCHESTER & SALISBURY)

DELETED

IV. Availability of Asbestos-Free Products in the U.S. Market

Turning now to the current availability of asbestos-free friction materials in the U.S. market, Abex has prepared Chart C to illustrate a few points. Based on industry availability estimates, it is clear that substitute materials for original equiment use are offered only on a limited basis by the industry as a whole. In contrast, and with the exception of industrial applications, Abex has achieved above-average market penetration for asbestos-free products among its original equipment customers, with the exception of rolled strips for passenger cars. Inasmuch as Abex's foreign affiliates have asbestos-free formulas for passenger car rolled strips in current use in Europe and South America, Abex could easily apply these formulas for domestic original equipment requirements following the qualification process. The chart makes a telling point in view of the E.P.A. observation on page 3750 of its proposal that some persons question whether there are safe substitutes for asbestos-based products in the aftermarket. Through its educational and promotional efforts in the past few years, Abex has been able to sell into the aftermarket asbestos-free products of an excellent quality for passenger car, light truck, and heavy duty truck braking applications. That degree of availability of a safe and a quality asbestos-free product for the replacement market is believed to be the best in the industry.

CHART C

ASBESTOS-FREE FRICTION MATERIAL

CURRENT AVAILABILITY

IN U.S. MARKETPLACE

DELETED

V. Original Equipment Manufacturers' Position on Asbestos-Free

Initial apprehension by original equipment manufacturers about the reliability of asbestos-free friction products appears to be waning.

It has been reported, in various government reports, that the original equipment manufacturers claimed:

- Complete redesign of braking systems would be required to accept asbestos-free products.
- Replacement asbestos-free products must be precisely the same as the original asbestos products.

The opinion of Abex is that complete redesign of the braking system is not necessary, and asbestos-free friction products can be developed and produced to replace asbestos products in the marketplace. The original equipment approval process is not more or less difficult when an asbestos-free product is used.

However, Abex believes sufficient testing is desirable to assure conformance to original equipment requirements. In Abex's opinion, the costs of such testing should be less than the $250,000 quoted by various trade organizations and government reports.

Original equipment industrial applications are, at present, a minor factor in Abex operations, and there are indications and reports that 75-80% of this market is already asbestos-free. This is primarily due to the concentration of smaller manufacturers in this business. Except for a few isolated applications, Abex asbestos-free formulations are available as candidates for most requirements.

The original equipment auto and truck manufacturers have implemented conversion to asbestos-free friction products as follows:

Heavy Truck

The attached chart D refers to Air Braked Trucks and Tractors. Asbestos-free was first introduced by Mack in 1979 and on all others as a DSO release (Dealer Service Option) in 1981. Its use has progressed steadily, although slowly, since that time. In many cases, the use has been held up at around 70% because no one has yet developed a suitable material for use on Wedge brakes and axles rated at 25,000 lbs. or higher - both of these require higher friction material that typically is very aggressive and tears up drums. Abex expects to begin marketing a new material for Wedge brakes within the next month which will help this situation, but no one has yet successfully developed a good material for the heavier axles.

As stated, the chart only addresses air braked trucks. In the case of hydraulic braked trucks at Ford, GM and IHC only, this represents approximately 50% of their total build. One could rate these at 100% asbestos-free (with insignificant exceptions) as they begin using 4-wheel disc brakes in 1983 with semi-metallic linings (Ford is an exception in that they use rear drum brakes, but also with asbestos-free materials).

If one desires to consider each company in total, for Ford, IHC, and GM, add 50% to one-half of the figure in the chart. Example: Ford 50% plus 50 x .7 = 85% of their total build.

Passenger Car/Light Truck

Again, the chart only refers to rear drum brakes. All of these companies began using front disc brakes in 1965 with semi-metallic lining. Currently, 100% of their vehicles use front disc brakes - 50% of their total brake build.

Ford Light Truck has taken the lead in the industry in converting to asbestos-free. The only reason it is not 100% is due to a lack of suitable material for its heaviest F-350 vehicle - about 10% of its production.

As indicated on the chart, other vehicle manufacturers are behind in conversion efforts, with some of the claiming that their customers are not asking for it. Probably only a legal requirement will force them to move faster.

Other companies are only replacing asbestos with asbestos-free as they introduce new model vehicles.

CHART D

ASBESTOS VS. ASBESTOS-FREE BRAKE LINING

HISTORY & CURRENT STATUS

DELETED

VI. Replacement Market Position

As mentioned in Section IV with reference to Chart "C", Abex counts itself among the responsible suppliers who have made substantial inroads in the replacement market with the sale of asbestos-free products. To the extent there are some laggards, the proposed E.P.A. ban can only serve to eventually make all suppliers responsive to the need to remove asbestos from friction products.

VII. Abex Asbestos-Free Formulations Currently Available

Chart E compares Abex currently available formulations with markets and products.

Most current formulations can be processed with existing tooling and equipment. However, it should be noted that to become more cost effective and to improve profitability in a very competitive market, it will be necessary to:

- Continue formula development.
- Invest in state-of-the-art equipment and tooling.
- Develop new technology.

CHART E

ASBESTOS-FREE FRICTION PRODUCTS

ABEX MATERIALS CURRENTLY AVAILABLE IN U.S.

DELETED

VIII. Abex Summary

In summary, Abex is ready and prepared to supply quality asbestos-free friction products in all lines to all markets.

All currently available asbestos-free formulations were developed with a view to be produced with existing processes and equipment with only minor tooling variations. This was done in the interest of capital conservation, but need not be a constraint in future developments.

Abex's Position:

- Support current pending regulations for the elimination of asbestos from friction materials.
- Continue the development of new technology and continue to focus major technical and manufacturing resources towards rapid asbestos-free conversion.
- Improve existing and future asbestos-free products with investment in state-of-the-art facilities equipment, tooling, and product research.

E-029(001)

62036
E29(1)

COMMENTS BY CHRYSLER CORPORATION
ON
DOCKET CONTROL NUMBER OPTS-62032
NOTICE OF PROPOSED RULEMAKING
ASBESTOS; PROPOSED MINING AND IMPORT RESTRICTIONS AND PROPOSED MANUFACTURING, IMPORTATION AND PROCESSING PROHIBITIONS

Chrysler Corporation submits the following comments on the referenced notice published in the Federal Register on January 29, 1986 (51 FR 3738). The notice proposes under section 6 of the Toxic Substances Control Act to restrict the manufacture, importation, and processing of asbestos in certain products and to phase out the use of asbestos in all other products.

Chrysler Corporation fully supports the spirit of the proposal to reduce and restrict the use of asbestos in the U.S. where demonstrated alternatives are feasible and available. In our opinion, a modification of alternative two represents the most practical approach to both government and industry in reaching this worthwhile goal in the near future.

Asbestos Substitutes

As the notice and Regulatory Impact Analysis recognizes, suitable asbestos alternatives are available for a great many applications at this time. Chrysler Corporation, and we believe other vehicle manufacturers, have been implementing these alternatives in the marketplace as rapidly as practicable. At this point in time, excluding certain brake applications, we foresee little difficulty in incorporating asbestos substitutes in all aspects of our motor vehicles in the next few years. However, as discussed in great detail in our response to Docket OPTS-211015 (copy attached), much more work needs to be done before asbestos can be totally eliminated from our brake systems.

Over the years, we have evaluated many asbestos-free candidate materials and compounds in our brake systems. Our experience shows that friction material formulations which provide acceptable performance in one application often proves to be unacceptable in another. Wide sweeping statements and claims which suggest that any asbestos substitute suitable for one brake system application is acceptable for another are totally unfounded.

Aftermarket Effect

Because every vehicle family is unique in its physical characteristics as well as its intended use, every friction material formulation utilized in a brake system must be tailored for that particular vehicle family. To re-engineer asbestos-free replacement parts for the multitude of vehicle families comprising the millions of vehicles in use today that were designed with asbestos containing brake systems would be a monumental task and is totally impractical.

In order to allow Chrysler and other manufacturers to continue to provide replacement components for those vehicles, the final rule must exempt asbestos containing brake components sold for replacement purposes. The alternative would be to open this market to untested and unproven substitute linings which may produce serious detrimental effects to motor vehicle safety.

Staged Phase-Out Approach

Chrysler Corporation cannot support regulating the use of asbestos through a gradual linear phase-out. The automotive industry does not introduce new models on a straight line linear basis. Consequently, such a scheme would create unresolvable planning problems and would be totally incompatible with the new vehicle introduction cycle.

In our opinion, a three-staged product approach for restricting asbestos with appropriate lead time is more reasonable and orderly from an automotive manufacturing position. In view of this, we strongly recommend a slightly modified version of the timetable proposed in alternative two as follows:

	Product Category	Time
o	construction products; clothing	two years after final rule
o	passenger car brakes; all transmission applications in motor vehicles	seven years after final rule
o	all other uses in motor vehicles	twelve years after final rule

This recommendation provides the necessary added lead time to develop successful asbestos alternatives for the more severe operating conditions experienced by truck brake systems.

Exemption Process

On an industry wide time scale, the invention of satisfactory asbestos alternatives is relatively new. As with any new technological area, numerous unanticipated and unforeseen pitfalls can occur during the inventing, testing, design and development process. Because of this, even the best predictions for incorporating asbestos alternative materials cannot be projected accurately. In order to accommodate the probability that despite our good intentions and diligent efforts, some asbestos substitutes will not be available to meet our recommended preconceived timetable, Chrysler believes that an exemption process must be included in any final rule addressing asbestos restrictions. In order to accomplish this, we strongly urge the EPA to publish an exemption process proposal with an appropriate comment period as soon as practicable, and before a final rule regulating asbestos use is promulgated.

Permit System

Chrysler opposes any form of a permitting system for regulating the use of asbestos. In our opinion, a permit system represents an unreasonable burden to industry in recordkeeping and reporting requirements. We point out that permits would be unnecessary with a stepped restriction on the use of asbestos as opposed to a phase-out. However, should the EPA determine that a permit system is necessary, we submit the following issues:

- The proposal suggests that permits are required for asbestos imported in unprocessed bulk, or in certain products listed in proposed paragraph 763.145. Our interpretation leads us to understand that under certain conditions, the same quantity of asbestos would require two or possibly more permits. For example, Chrysler imports bulk asbestos for processing into brake pads. We then export those pads to our vehicle assembly plants in Canada and other locations outside the U.S. for use on motor vehicles ultimately shipped into the U.S. Under this scenario, we believe that two permits would be required for the same asbestos end use. We believe that the regulation must take into consideration this form of transaction and set the number of permits issued accordingly.

- The EPA proposes to issue permits based on the average amount of asbestos imported in calendar years 1981, 1982 and 1983. As the EPA is aware, the prevailing economic conditions in the U.S. during those years contributed to a very depressed automotive market. As a result of reduced motor vehicle production, the total amount of asbestos used by Chrysler during the base year period was uncharacteristically low. In an effort to compensate for this anomaly, we recommend that the EPA issue permits based on 120 per cent of the average amount of asbestos imported in the three year period.

Labeling

Chrysler Corporation presently labels all packages containing parts having asbestos content with a cautionary label indicating 1) the product contains asbestos, 2) the user should avoid creating dust, and 3) that breathing asbestos dust may result in serious bodily harm. In addition, a similar cautionary warning is currently placed in all of our service/shop manuals where exposure to asbestos dust may be encountered while servicing our products. In our opinion this labeling system, which has existed for a number of years, provides adequate warning at the point where exposure to asbestos dust is most likely to occur. We do not believe that any more stringent form of labeling is necessary.

Docket #62036
E-029 (002) File
ENCL
62036
E29(2)

CHRYSLER
CORPORATION

R. O. SORNSON
DIRECTOR
REGULATORY RESEARCH AND ANALYSIS

March 13, 1985

TSCA Public Information Office (TS-793)
Office of Toxic Substances
Environmental Protection Agency
Room E-107
401 M Street, S.W.
Washington, DC 20460

Re: Proposed Prohibition on Use of Asbestos in Motor Vehicle Brake Linings
Document Control Number OPTS-211015

Chrysler Corporation submits the following comments in regard to a notice published in the Federal Register on December 19, 1984 (49 FR 49311). The notice requests comments on the health risks presented by the use of asbestos in motor vehicle brake linings. The EPA notice responds to a petition filed by the National Resources Defense Council which seeks a ban on the use of asbestos in those applications.

Chrysler Corporation recognizes the fact that exposure to certain levels of asbestos fiber can be a health risk. However, it is generally agreed that the degree of risk is dependent on the type of asbestos fiber. The only type used in the manufacture of brake linings is chrysotile which has been shown to be the least hazardous of the various asbestos forms. Moreover, there is evidence that the physical and chemical characteristics of the material released to the atmosphere as brake linings wear are not asbestiform in nature. Research conducted by the National Institute for Occupational Safety and Health (NIOSH) has indicated that this material is predominantly a thermally degraded compound and is almost entirely non-fibrous. Until there is better evidence that the material released during braking is indeed asbestiform in nature, we do not believe that the EPA should impose a regulation prohibiting the use of asbestos in motor vehicle brake linings. Even though these many uncertainties exist, we are committed to the elimination of asbestos from brake linings installed on the vehicles we manufacture.

We have been working diligently for a number of years with the major brake lining suppliers in the U.S. in an effort to find substitute materials for brake linings which do not contain asbestos. Our experience to date shows that the development of substitute materials is a very difficult and time consuming task. It has been fraught with numerous problems, many of which are recognized in the subject notice. Because of the unresolved problems associated with many currently available substitute materials, we cannot project at this time when our suppliers will be able to provide satisfactory asbestos-free brake linings for incorporation on all of our vehicles.

The development of satisfactory asbestos-free brake lining materials will take time. Over the years consumers in the U.S. have developed the expectation that vehicle brake systems will provide safe, reliable performance during many miles of operation without maintenance and will be noise-free. Many years were required for vehicle manufacturers and suppliers to develop the expertise required to provide asbestos lining compounds which meet these consumer demands and our stringent safety and performance requirements under the multitude of widely differing environmental and driving conditions experienced in the U.S. These lining materials also had to be engineered to provide balanced and consistent stopping ability under all types of vehicle loading conditions, under a very wide variety of brake temperature conditions and with "green" and used linings.

New asbestos-free brake lining compounds and formulations must be developed to meet these same objectives. Because brake performance is important to vehicle safety, it must not be compromised by a premature switch to substitute materials. Some substitute materials have been developed and the use of asbestos material has been substantially reduced, but there is still much more work to be done before it can be totally eliminated. Currently, all but one vehicle that Chrysler manufactures has semi-metallic front disc brake pads. However, we must still depend on asbestos as an underlayer medium on most applications to eliminate stress cracks that appear during the bonding or riveting of the friction material to the brake pad support plate. No entirely satisfactory material has been found to date which will provide the cushioning effect provided by the thin asbestos-based underlayer material. Alternate materials for the underlayer are being evaluated in hopes of producing pads which are completely free of asbestos.

We are working to employ asbestos-free substitute linings on new model vehicles as part of the design and development process. This process has not been without problems, however. Recently we were forced to revert to asbestos-containing brake linings on two soon-to-be-introduced vehicles because of heavy disc brake rotor scoring and inconsistent brake performance with asbestos substitutes. These difficulties appeared very late in the vehicles' development program and may ultimately cause a production delay. However, asbestos-free linings are planned for several other applications on 1986 model year vehicles. Because of weight distribution, suspension characteristics and other factors, each vehicle has unique braking system requirements. Consequently, a particular lining formulation that is acceptable on one vehicle may prove to be unacceptable on another.

In view of the complexity involved with the development of a new brake system, we begin nearly three years before the first vehicle rolls off the assembly line. The first step in the process is the establishment of vehicle performance goals and objectives. These include all the requirements of Federal Motor Vehicle Safety Standard 105, a minimum brake lining life of 50,000 miles under normal driving conditions, and noise-free operation for the life of the vehicle. These criterion along with other design parameters are conveyed to our friction material suppliers for candidate material selection. During this critical period of development, we are literally totally dependent on the recommendations they provide. Controlled laboratory tests narrow the field of candidates to the final material to be used. Vigorous tests during highway, city traffic, and mountain grade driving fine tune the system to ensure that it will meet our stringent safety and performance requirements and consumers' demands for quiet, effective and trouble-free performance.

In view of the controversy and the problems encountered with the development of asbestos substitutes, Chrysler Corporation believes that it would be inappropriate to prohibit the use of asbestos in brake linings at this time. Chrysler, and we believe the other vehicle manufacturers, are moving to asbestos-free brake lining materials as rapidly as technology will permit. Any regulation will not increase the rate of this changeover and forcing the use of asbestos-free materials at a premature date could very well result in compromises in brake performance which are not in the interest of motor vehicle safety.

In addition to these comments, Chrysler Corporation participated in the development of the comments submitted by the Motor Vehicle Manufacturers Association of the United States. We endorse those comments and by reference incorporate them as a part of our response.

Sincerely,

R. O. Sornson

R. O. Sornson

BRS/ma

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E35a

DEERE & COMPANY

JOHN DEERE ROAD, MOLINE, ILLINOIS 61265-8098 U.S.A.

OPTS Docket #62036 Asbestos Ban
MC/E 35a File
REQ TO PART

RALPH D. GROTELUESCHEN
Director
Safety, Environment
& Energy Management

24 June 1986

Document Control Officer (TS-793)
Office of Toxic Substances
Environmental Protection Agency
Room E-209
401 M Street, S.W.
Washington, D.C. 20460

Dear Sir:

Docket No. OPTS-62036
Asbestos, Proposed....Manufacturing,
Importation and Processing Prohibitions (40CFR Part 763)
Request For Opportunity to Present Comments At
Public Hearing on July 15

Please consider this an official request for Deere & Company to present comments at the scheduled public hearing on proposed asbestos prohibitions on July 15.

Deere & Company manufacturers a broad line of agricultural, industrial, and consumer product machinery. In order to service our current line of products and to produce quality replacement parts for our past lines of machinery, we have identified 1,450 part numbers containing asbestos subject to this regulation. In spite of our past long-term commitment to eliminate asbestos from our product line, our commitment to convert to asbestos-free products as soon as reasonable, plus other factors makes abrupt conversion of 70% of our asbestos products to asbestos-free materials impossible or unacceptable from a risk management standpoint.

The issues we plan to address are:

1. The risks we must manage to convert to asbestos-free products that we believe received inadequate consideration by the Agency.

2. Inability of our industry to directly apply use of asbestos-free products in the automotive industry.

3. Concerns necessary to supply used parts to the agricultural industry where machines are routinely in use that were designed more than 25 years ago.

DEERE & COMPANY

4. Concerns in placing research on a schedule, particularly in achieving a first year asbestos product substitution rate of 70%.

5. Provisions for managing exceptional situations that do not turn out to match the Agency's assumptions in replacing asbestos products.

6. Support our written statement.

I believe I will require 25-minutes to complete my statement and to facilitate travel would prefer to comment after lunch.

I, Ralph Grotelueschen, will be the only person commenting for Deere & Company.

Thank you for your consideration.

Yours truly,

Ralph D. Grotelueschen

Ralph D. Grotelueschen

/dk

c: John Rigby - U.S. EPA (TS-794)

OPTS Docket # 62036 Asbestos Ban
M/C E 35b File
w/2 encls

DEERE & COMPANY

JOHN DEERE ROAD, MOLINE, ILLINOIS 61265-8098 U.S.A.

63-8600159

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E35b
w/2nclosures

RALPH D. GROTELUESCHEN
Director
Safety, Standards, Environment
& Energy Management

3 July 1986

Document Control Officer (TS-793)
Office of Toxic Substances
U.S. Environmental Protection Agency
401 M Street, S.W. - Room E-209
Washington, D.C. 20460

Attention: Pat Grim

Attached is a retyping of original comments on asbestos with confidential business information deleted. We understand our original statement will go to confidential file while this statement will be available for public review and inspection.

Please call again (309/752-5151) if you have any questions regarding our comments.

Respectfully,

Ralph D. Grotelueschen

Ralph D. Grotelueschen

/dk

Att.

FORD MOTOR CO.
OPTS Docket #62036 Asbestos Ban File
MC/E
w/1 Encl

1986 JUL -2 AM 9:35

62036
E46

JUL -2

V. H. Sussman, Director
Stationary Source Environmental Control
Environmental and Safety Engineering

Ford Motor Company
Suite 608
15201 Century Drive
Dearborn, Michigan 48120

June 26, 1986

Document Control Officer (TS-790)
Office of Toxic Substances
Environmental Protection Agency
Room E-201
401 M Street S.W.
Washington, D.C. 20460

Attention: Docket Control No. OPTS-62036A

Subject: Proposal to Amend 40 CFR 763 -- Asbestos; Proposed Mining and Import Restrictions and Proposed Manufacturing, Importation and Processing Prohibitions 51 Fed. Reg. 3738 (1986), as corrected at 51 Fed. Reg. 6571 (1986)

Ford Motor Company ("Ford") hereby responds to the Agency's request for comments on the above-referenced proposed rule. Ford adopts the comments submitted in this docket by the Motor Vehicle Manufacturers Association of the United States, Inc. ("MVMA") to the extent that MVMA's comments are consistent with the following.

Ford opposes the proposed permit system for allocation of asbestos during a phasedown of asbestos mining and importation. The proposed permit system would impose significant costs on the regulated community for administration, permit acquisition, tracking asbestos content of imported products, reporting and recordkeeping; these costs are understated in the Regulatory Impact Assessment.

The permit system would discriminate against importers of motor vehicles and vehicle components. The baseline years for initial allocation of permits are years in which the automobile industry and the economy were in a downturn. Additionally, the amounts of asbestos imported in automotive products during the baseline years do not reflect the change in such amounts occasioned by the more recent shift toward multinational manufacture and sale of vehicles and components. Ford, for example, imported far fewer asbestos-containing vehicles in those base years than it has imported more recently. To now allocate permits on the basis of amounts imported during those unrepresentative base years would unduly penalize Ford (and presumably other vehicle importers).

The permit system also ignores the practice in the automobile industry of introducing changes during model redesign. These changes such as substitution of non-asbestos materials are not the uniformly stepped incremental changes envisioned by the proposed 3% per year reduction, but are major steps which might affect 30% of production in a single year. Each of these major changes involves substantial engineering/design/testing time and expense, tooling design/manufacture time and expense, facilities design/construction time and expense, and, with the permitting system, additional administration/overhead time and expense, all of which will be reflected in consumer cost and which, when uncoordinated with model changes, will be significantly greater than forecast by the RIA.

Ford supports a reasonable fixed timetable for removal of asbestos products, coupled with a procedure for exempting those essential asbestos products for which no reasonable alternatives exist. In this regard Ford's suppliers of asbestos products inform us that they do not yet have practicable asbestos-free substitutes for certain asbestos-containing components such as heavy truck brake blocks and disc pads, and some duo-servo car and light truck drum brake linings, engine manifold gaskets, and exhaust system gaskets and heat shields.

Motor vehicle safety must not be compromised. Even a slight increase in traffic fatalities would eliminate any benefits from the reduction in cancer cases projected by the Agency.

The Agency has requested comments on whether asbestos brakes now in use may be safely replaced by asbestos-free brakes when they wear out. Ford has already touched on this question in its response of March 15, 1985 (Document Control No. OPTS-211015). A simple assumption that a brake shoe made of one material can be substituted for a shoe made of another material without extensive engineering evaluation is not correct. Many different performance, noise, durability, and other problems can occur when a friction material is introduced into a system without careful evaluation. Many complex issues must be researched including, but not limited to, thermomechanical stability ("hot spotting" and "banding"), brake fluid displacement, fluid boil (semimetallic and metallic linings), morning sickness (effects due to moisture), and different friction levels. For example, Ford Heavy Truck Engineering recently found that in some

2

vehicles, substituting non-asbestos brake shoes for those containing asbestos necessitated major changes in the air brake actuation systems including larger reservoir and brake chambers and increased compressor capacity. The extension of this experience to the 192 different brake systems and 51,000 parts currently in inventory at the Ford Parts and Service division which contained asbestos is simply enormous. This large inventory of parts is held as parts replacement for vehicles designed over the past 29 years. Thus, Ford strongly recommends that EPA exempt the manufacture and sale of asbestos-containing service components for vehicles which were originally designed and equipped with systems that consist of asbestos-containing brake shoes and pads.

The Agency also has requested comments on labeling of asbestos-containing parts subject to regulation 5 or 10 years from now. Ford currently labels the package of its asbestos-containing brake shoes, brake pads, and clutch plates with a warning that the parts contain asbestos fibers and that breathing asbestos dust may cause serious bodily harm. The label also specifies precautions which should be taken during service. Sample labels for the packages for both brakes and clutches are attached. Ford sets forth more detailed instructions for safe servicing of these friction products in its shop manuals.

These types of warnings directed to those about to install asbestos-containing friction components most effectively protect those most likely to come into contact with the dust residues of braking and clutching. A simple content warning provides little useful information to the consumer because it gives no information about a specific potential hazard and no information about how to avoid that hazard. Labeling of asbestos components as installed in vehicles is impracticable. Many parts are too small to be labeled and the environment of some parts, e.g., the high-temperature environments of brakes and clutches, would destroy labels. The point at which the warning, when necessary, should be delivered is at the replacement part/service operation.

Very truly yours,

Victor H. Sussman

Attachment
jlt3/L

HONDA MOTOR CO., Inc

OPTS Docket #62036 Asbestos Ban

MC/E 58 File

HONDA

AMERICAN HONDA MOTOR CO. INC.

P.O. BOX 50 — 100 W. ALONDRA BLVD., GARDENA, CALIF. 90247

CABLE ADDRESS — AMEHON, GARDENA, CALIF. (213) 327 – 8280

1986 JUN 24

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E58

June 19, 1986

Document Control Officer (TS-793)
Office of Toxic Substances
U.S. ENVIRONMENTAL PROTECTION AGENCY
Room E-209
401 M Street, S.W.
Washington, D.C. 20460

Docket Control Number: OPTS-62036

Dear Sir:

Enclosed are the comments of Honda Motor Co., Ltd. regarding EPA's proposal to prohibit the manufacture, importation and processing of asbestos in certain products and to phase-out the use of asbestos in all other products.

Yours truly,

AMERICAN HONDA MOTOR CO., INC.

Brian Gill
Manager
Certification Department

BG:lw

Enclosure

asbestos.txt

62036
E58(1)

COMMENT OF HONDA MOTOR CO., LTD.
REGARDING
EPA'S PROPOSAL TO PROHIBIT THE
MANUFACTURE, IMPORTATION AND PROCESSING
OF ASBESTOS IN CERTAIN PRODUCTS
AND TO PHASE-OUT THE USE OF
ASBESTO'S IN ALL OTHER PRODUCTS

6/16/86

Honda appreciates the opportunity to participate in this rulemaking.

We strongly support the comments submitted by the Automobile Importers of America, Inc. and we wish to emphasize the following important points.

1. Enforcement

   If, in fact, the regulation of asbestos use in automotive parts can be justified, EPA should set-up a timetable for the phase-out of asbestos containing parts on an orderly, industry-wide basis. This timetable should be based on model-year and must consider the necessary leadtime for developing and testing asbestos free parts to replace the current parts.

2. Applicability

Any asbestos control rulemaking should address only vehicles manufactured after the effective date. To require manufacturers to develop and provide asbestos-free replacement parts for in-use vehicles involves a very large effort with a decreasing benefit, as the number of these vehicles and their use is decreasing.

For example, the engineering effort needed to provide asbestos free brake pads and shoes should include the re-design of other brake system parts in order to maintain the original brake system performance as the frictional characteristics of the non-asbestos pads and shoes do not match those of the original parts. This could significantly increase the cost of brake repairs to these older vehicles and cause an adverse effect on vehicle safety due to the postponement of needed repairs.

3. Exemption

Automotive parts such as gaskets and insulation material from which the emission of asbestos particles is very unlikely, should not be included in any rulemaking.

OPTS Docket #62036 Asbestos Ban
MC/E 71 File

62036
E 71

JUL 8

MERCEDES-BENZ OF NORTH AMERICA, INC.

KARL-HEINZ FABER
VICE PRESIDENT
PRODUCT COMPLIANCE AND SERVICE

ONE MERCEDES DRIVE
P. O. BOX 350
MONTVALE, NEW JERSEY 07645
(201) 573-2614

June 30, 1986

1986 JUL -7 PM 2:06

Document Control Officer (TS-793)
Office of Toxic Substances
Environmental Protection Agency
Room E-209
401 M Street S.W.
Washington, D.C. 20460

Subject: Asbestos: OPTS-62036

Gentlemen:

Pursuant to the invitation for comments published in the Federal Register of January 29, 1986, I am pleased to enclose the following comments of Mercedes-Benz of North America.

Yours truly,

K. Faber

Enclosure

62036
E71(1)

Submission of Mercedes-Benz of North America, Inc.

to the

Environmental Protection Agency

June 25, 1986

This submission is filed pursuant to the notice of a proposal to prohibit the manufacture, importation and processing of asbestos in certain products.

40 CFR Part 763

OPTS - 62036, FRL 2947-3

January 29, 1986

TABLE OF CONTENTS

Comments of Mercedes-Benz of North America to the notice of a proposed rule to prohibit the manufacture, importation and processing of asbestos in certain products (51 Fed. Reg. 3738, January 29, 1986).

I. INTRODUCTION

A. Identification of the Importer

Mercedes-Benz of North America, Inc. (MBNA) is the importer of motor vehicles and spare parts with the trade name and mark "Mercedes-Benz". The importation includes brakes, braking systems and parts thereof, excluding brake linings. The latter equipment is purchased from European manufacturers.

B. Product Characterization

MBNA imports passenger cars and all major components for these vehicles, such as running gear, body work, engine, transmission, which have been designed and manufactured to assure a final product which is a fully integrated unit.

The vehicles' brakes are considered as one of the systems to ensure safe operation of transport. Such systems themselves are composed of a large number of elements which cannot be altered or changed simply without interference into the balanced performance of such a safety item.

II. BRAKING SYSTEMS

For the specific needs of the different kinds of road vehicles, a number of braking systems represent the State of the Art.

For passenger cars, the vacuum booster assisted hydraulic braking system is the normal design, either using drums or discs or a combination of both.

III. PERFORMANCE OF BRAKING SYSTEMS

A well designed and properly maintained braking system will slow down a vehicle in such a way that the steering of the vehicle is not, or at least only slightly, interfered with. To achieve this goal, the braking forces have to be carefully distributed between the axles and wheels of the vehicle concerned. Normally, the driver has no influence on this safety related brake force distribution. It has to be achieved by the braking system design, which, however, has to accomplish this task under all conditions imposed by the driver. Among such conditions are speed, deceleration, weight per wheel, height of the center of gravity of the load and the driving environment.

Design data in relation to braking performance are - inter alia:

-- Actuating effort on the brake pedal.

-- Booster dimension and performance - if applicable.

-- Brake cylinder dimensions, braking fluid pressure.

-- Mechanical characteristics of the interacting brake cylinder and brake drum or disc combination.

-- Reaction and release times within the transmission of power braking systems.

-- Dimensions of drums, discs, wheels, tires.

-- Temperature influences on materials.

-- Friction characteristics of brakes as a function of temperature, velocity and pressure.

A safe braking system is a well balanced design. Influencing one of its parameters alone, e.g. by replacing asbestos in friction materials, necessitates reconsideration of the complete system. Immediate availability of substitutes is not given for all applications (see Section V).

IV. EVALUATION OF FRICTION MATERIALS

The mechanical properties of friction materials for vehicle brakes obviously should be such as to allow the safe use of these materials under conditions as prescribed in Sections II and III. Accordingly, the quality of friction materials is identified and assessed by terms as:

-- Coefficient of friction.

-- Brake factor, i.e. friction drag/actuation force.

-- Resistance to wear.

-- Mechanical strength.

-- Thermal conductivity.

-- Corrosion resistance.

-- Acoustical properties.

V. AVAILABILITY OF SUBSTITUTE FRICTION MATERIALS

In consideration of the criteria mentioned in Sections II, III and IV, it is possible to develop, design, test and produce a limited number of braking systems with brake linings or pads that no longer contain asbestos. For example, the rear brake pads, as well as the parking brake linings, are asbestos-free on all MB passenger cars. The new Mercedes-Benz intermediate class series ("300" models) are currently equipped with asbestos-free brake pads on all wheels. In addition, asbestos has been removed from all clutch linings of our cars.

The other asbestos containing systems would have to be redesigned so as to accommodate non-asbestos friction materials. This process of redesigning and testing is extremely time consuming and has not yet led to results that satisfy our criteria. The problems encountered are basically the following:

-- The brake factor level as compared to customarily approved linings is either too high or too low;

-- The brake factor scatters - in a non-permissible range - as a function of miles travelled, speed and temperature;

-- High wear of pads and discs;

-- Insufficient mechanical strength;

-- High thermal conductivity;

-- Low corrosion resistance; and

-- Uncontrolled noise generation.

These problems are less significant for rear brakes because the requirements regarding rear brakes are different from those for front brakes.

The adaptation will certainly take another period of several years so that an immediate phase-down of asbestos as proposed in the NPRM and in Alternative 3 would unavoidably lead to not meeting our performance criteria.

VI. CONCLUSIONS

1. In view of the necessity of redesigning the braking systems as mentioned in Section V, a ban or even a phase-down soon after promulgation would lead to an insufficient development period for new front braking systems which must be balanced with the rear axle systems.

2. As we are not yet in a position to clearly identify the timely needs to solve all existing problems, we would appreciate a regulation that foresees a ban of asbestos containing friction products only after a transition period of at least five years including the possibility of exemptions as provided for in the NPRM. These exemptions are indispensable with respect to replacement parts, since braking systems of in-use vehicles originally developed to operate with asbestos-containing linings or pads cannot be rebuilt or recertified so as to accommodate asbestos-free substitutes.

With respect to gaskets, particularly cylinder head gaskets, even longer lead times for developing and testing substitute materials may be necessary because of the required unique heat resistance properties. Therefore, although none of the alternatives appear to deal with the real-world problems confronting a vehicle manufacturer, as described above, Alternative 1 is preferable over Alternative 2.

3. All of our technical assumptions are made in the light of the existing provisions of FMVSS 105. This Standard is, however, in the process of being reconsidered by NHTSA with particular emphasis on front-to rear brake balance. The eventual impact of such alterations cannot be assessed yet and may, therefore, lead to further delays.

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1986 JUN -2 AM 11:03

VOLKSWAGEN OF AMERICA, INC.
888 W. Big Beaver
P.O. Box 3951
Troy, Michigan 48007-3951
Tel. (313) 362-6000
WU Telex — 230 628

May 21, 1986

Document Control Officer (TS-790)
Office of Toxic Substances
U.S. Environmental Protection Agency
Room E-201
401 M Street S.W.
Washington, D.C. 20460

Re: Proposed asbestos regulations concerning restrictions on mining and importation, and prohibitions of the manufacturing and processing of certain asbestos - containing products.

Document Control Number OPTS-62036A

Docket Clerk:

Volkswagen of America, Inc., Volkswagen and Audi AG (hereafter referred to as Volkswagen) submits the following comments in regard to a proposed rule published in the Federal Register on January 29, 1986 (51 FR 3738). The proposed rule requests comments on the feasibility and effectiveness of these regulations, including alternative approaches.

Volkswagen recognizes the fact that exposure to certain levels of asbestos fiber can be a health risk. However, it is generally agreed that the degree of risk is dependent on the type of asbestos fiber. Chrysotile is the only form of asbestos used by Volkswagen, for new drum brake linings, and replacement linings for older vehicles. However, Chrysotile is considered the least hazardous of the various asbestos forms. Nevertheless, the European Economic Community (which Germany is a member of) and Canada have recognized the differences in asbestos forms and accordingly promulgated standards for the protection of worker's health from the more toxic forms of asbestos. This situation, unfortunately, is not true in the U.S. to the extent that the Occupational and Health Administration (OSHA) does not recognize these toxicological differences, and adopts requirements in factories that perhaps are more stringent than necessary. Volkswagen thereby believes that the health risks associated with brakes containing a less hazardous form of asbestos has been overstated by EPA, and should not be considered as justification for these proposed regulations.

Volkswagen, together with its suppliers and other automotive manufacturers, have been working diligently for a number of years to find substitute materials for brake linings which do not contain asbestos. There are very few alternate materials which have the total combination of the desirable characteristics found in asbestos. Developing and approving acceptable substitute materials requires extensive research and testing programs. A substitute which results in unacceptable vehicle performance or safety, or is more harmful than asbestos to workers, is an unacceptable substitute. In view of this dilemma, these proposed regulations will not decrease the time necessary to develop suitable asbestos-free replacements. For the most part, Volkswagen will have asbestos-free brake linings across its entire product line beginning in model year 1987.

The agency has requested comments regarding their proposed 10-year phasedown approach, as well as three other alternative approaches. To begin with, Volkswagen believes that none of the approaches meet the requirements outlined in section 6 of the Toxic Substances Control Act (TSCA) as it directs the agency to select the most cost effective means in reducing the public health risk. This applies mainly to the asbestos clothing and construction products category. Therefore, the immediate ban of the asbestos clothing and construction products soon after promulgation of the rule, and gathering of additional information on all other asbestos products would have been the most cost effective means. Furthermore, EPA's own cost estimates shown in table VI of the proposed rule indicates that alternatives 1 and 3 are more cost effective than their proposal.

The ten year phasedown scheme with mandatory permits, banking, trading, recordkeeping and reporting requirements are extremely burdensome and unwarranted. At the very most this phasedown scheme with its associated requirements should apply only to those parties which mine and manufacture asbestos products, not to automobile manufacturers who import automobiles which have a small amount of parts that contain asbestos. Volkswagen proposes that automobile manufacturers be exempt from such requirements as it relates to the importation of automobiles and all parts described in the friction products category and automotive gaskets.

In developing a method to eventually eliminate asbestos containing parts in automobiles or other motor vehicles (domestic or imported), Volkswagen thinks a series of "Fixed Time Limits" (FTL) would be more appropriate than a phasedown scheme which includes the averaging of base years 1981-83. These FTL's would apply to new vehicles for which there was sufficient lead-time to make necessary design changes to incorporate non-asbestos substitutes. All automotive manufacturer's would have to comply with these FTL's or petition the agency for an exemption. Volkswagen is requesting EPA to consider the following examples:

Product	FTL
Clutch facings	4 years
Transmission parts	4 years
Gaskets	4 years
LDV front disc-brake pads	4 years
LDV rear drum brake linings	6 years
Medium & HD brakes	10 years

Exemptions under this proposed scheme should be allowed if non-asbestos substitutes were not yet developed or other safety and performance criteria could not be met. This approach is much simpler to enforce and eliminates the need for the issuance of permits.

The last issue that Volkswagen would like to address is service replacement parts. This issue is of particular concern to us because of the continued use, and availability, of asbestos-containing parts in our older vehicles. Specifically, brake systems in these older vehicles were designed to meet performance goals and objectives. The cost of retrofitting or redesigning these brake systems to meet the same performance goals and objectives with non-asbestos substitutes is very expensive and impracticable. A brake system is not simply a collection of disparate parts -- pads, shoes, discs, drums, etc. The pads and shoes of a vehicle that use asbestos friction materials have very different properties from the pads and shoes of those that do not contain asbestos. Therefore, one cannot simply use a non-asbestos substitute brake shoe in conjunction with a drum that was designed for an asbestos-containing friction material. Likewise, a disc brake that was designed for a semi-metallic friction material will not perform satisfactorily if an asbestos-containing pad is substituted. Volkswagen believes that it would be inappropriate to prohibit or phaseout the use of asbestos parts in out-of-production vehicles, for which the consuming public rightfully expects aftermarket parts will remain available throughout the vehicles useful life. Thus, a permanent exemption should exist for those replacement parts imported to, or manufactured in, the U.S. for out-of-production vehicles from both a cost-effective and safety standpoint.

In summary, Volkswagen recognizes that the majority of the asbestos applications in motor vehicles have acceptable substitutes in various stages of development. However, there are certain critical parts for which acceptable substitutes may take a few more years (i.e. cylinder head, exhaust manifold, and other small flat gaskets). Furthermore, Volkswagen would like EPA to consider the abandonment of their 10-year phase-out scheme including all of the proposed permit requirements in favor of the Fixed-Time-Limit as mentioned above.

In addition to these comments, Volkswagen participated in the development of the comments submitted by the Motor Vehicle Manufacturers Association of the United States. We endorse those comments and by reference incorporate them as a part of our response.

Sincerely,

Wolfgang Groth

Wolfgang Groth
Manager
Emission Regulations & Certification

cc: Mr. Edward A. Klein, Director
TSCA Assistance Office
U.S. EPA

General Motors

~~Raymark Industries~~ Exhibit______

OPTS 62036 Asbestos Ban

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General Motors Corporation
Statement on
EPA Proposed Asbestos Mining and Import Restrictions and
Manufacturing, Importation and Processing Prohibitions
July 16, 1986

Opening Remarks at Public Hearing on Asbestos Ban by
Joseph P. Chu, Ph.D., P.E.
Assistant Director, Plant Environment
General Motors Environmental Activities Staff

My name is Joseph P. Chu. At the Plant Environment department of the GM Environmental Activities Staff, I am the Assistant Director responsible for coordination of GM's programs for compliance with TSCA requirements. General Motors has several serious concerns with EPA's proposed ban. Therefore, we are urging EPA not to adopt the proposed regulations.

General Motors is a manufacturer and user of asbestos friction materials and a user of other asbestos products. Our products which contain asbestos include brake systems, transmission systems, gaskets, adhesives, and sound deadeners.

We have submitted our comments and, today, three GM experts are with me. Each will be making a statement and then I will follow with our closing remarks.

The three GM experts, in the sequence of their statements, are:

Dr. William H. Krebs, Director of Toxic Materials Control Activity of the GM Industrial Relations Staff.

Mr. Robert L. LeFevre, Manager for Safety Standards and Security, Automotive Safety Engineering of the GM Environmental Activities Staff.

Mr. Thomas M. Johnson, Manager of the Brake and Bearing Systems Center, Current Product Engineering of the GM Current Engineering and Manufacturing Services Staff.

Now, may we begin with Dr. Krebs.

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OPTS Docket # 62036 Asbestos Ban
General Motors Corp Exhibit________ ig
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General Motors Corporation
Statement on
EPA Proposed Asbestos Mining and Import Restrictions and
Manufacturing, Importation and Processing Prohibitions
July 16, 1986

Statement for Public Hearing on Asbestos Ban by
Robert L. LeFevre
Manager, Automotive Safety Engineering
General Motors Environmental Activities Staff

My comments today will address General Motors concerns regarding the potential impact of the proposed rulemaking on the safety of automotive brakes and the compliance of brake systems to safety regulations.

Assuring that vehicles are fitted with brake systems which fully meet the need for motor vehicle safety is a major responsibility of automotive engineers. Since 1968 the National Highway Traffic Safety Administration of the Department of Transportation has been active in establishing Federal Motor Vehicle Safety Standards which prescribe both design and performance specifications for brake systems on new vehicles.

At the present time standard FMVSS 105 regulates hydraulic brakes, and FMVSS 121 addresses air brake systems. In similar ways, brake systems for vehicles which are to be sold in other countries are subject to certain national or regional regulations. As General Motors detailed in its written comments on this asbestos rulemaking, efforts are also underway to reconcile the regulatory differences by developing an internationally harmonized brake standard.

Taken individually or collectively, these standards dictate compliance levels for a multitude of performance characteristic of brake systems and as a result have dominant influence on brake system design decisions. Despite this number of regulations, questions as to what constitutes fully acceptable safety performance for brake systems continue to surface. General Motors and other manufacturers have repeatedly found themselves involved in discussions and debates with the NHTSA Office of Defects Investigations regarding the real-world adequacy of brake systems even though these systems fully conform with all regulatory requirements. In addition to the legal constraints, our customers have additional brake performance expectations in areas such as durability and noise.

Independent of all of the safety regulations, discussions about brake system performance and customer demands, the EPA has proposed to ban asbestos, one of the few materials which has the proven ability to function and survive in the hostile environment of brake systems. This action in essence calls for a forced change in the fundamental composition of most brake friction materials.

Inasmuch as there is no one-for-one substitute for asbestos, this change will require offsetting changes in brake system design. As General Motors advised in its written comments, some of its disc brake pads and virtually all of its drum brake linings are made with asbestos to achieve the essential blend of strength, friction stability and temperature capability. Some other materials have worked well in some applications; however, no effective substitute has been found for other applications.

The elimination of asbestos from the approximately 80 systems which currently use this material would be an enormous undertaking, and total success within the timeframes cited by the agency is not certain. In light of the difficulties which have been encountered in the past in finding materials which will yield system performance meeting all regulatory, safety and customer demands, we must urge the agency to proceed with caution along the lines which we have outlined in our written comments.

The composition of brake friction materials used for replacement purposes is also of serious concern to General Motors. As the EPA may be aware the performance of brake systems already operating on the public roads is not regulated, and federal regulations do not even acknowledge replacement brake friction materials. However, our experiences have taught us that replacement materials and systems which have been serviced must provide substantially the same performance as original equipment. If asbestos were to be banned as the agency has proposed and therefore were to be unavailable for use in replacements, it is probable that some applications would require that the sealed hydraulic systems be opened up to replace brake cylinders or other components to compensate for the different friction properties of the substitute materials.

For example, if the substitute materials had 10% lower friction, it might be that the best way to recover the lower system output would be by increasing the size of the wheel cylinders or to change operating pressure. We are convinced that customers would reject such costly part changes. To avoid causing significant changes in brake performance for cars designed to use asbestos friction materials, we urge the EPA to configure any asbestos rule so that it allows existing vehicles which are validated with asbestos linings to be serviced with asbestos linings. We believe that this strategy is consistent with the EPA's intent to curtail the use of asbestos, because these applications for asbestos will subside naturally as the vehicles are retired.

In summary, it is essential that the EPA collaborate with the NHTSA on this rulemaking to assure that any change in brake system performance which is made necessary by an EPA rule regarding asbestos usage is consistent with motor vehicle safety needs. It is important that both the content of any rule and any implementation schedule be responsive to both health and safety needs. Such a joint effort can assure that a potential conflict betwen NHTSA and EPA regulatory requirements will be avoided.

General Motors Corporation
Statement on
EPA Proposed Asbestos Mining and Import Restrictions and
Manufacturing, Importation and Processing Prohibitions
July 16, 1986

Statement for Public Hearing on Asbestos Ban by
Thomas M. Johnson
Manager, Brake & Bearing Systems Center
General Motors Current Product Engineering

General Motors currently has in production approximately 80 unique brake systems. It sells replacement parts for many additional systems including more than 100 for vehicles produced since just 1982. In addition to federal laws governing brake systems, each system must provide vehicle owners with satisfactory performance for a wide array of conditions. A partial listing of customer requirements includes cold performance, hot performance, park brake effectiveness, noise, wear out life, friction stability, corrosion resistance, heat transfer rate, and fade resistance. These brake systems must satisfy customers ranging among the "old man of the mountain" who spends his retirement driving up and down pikes peak every day, rural mail carriers in Minnesota, New York city taxi cabs, and Mojave Desert park rangers. Though colorful to describe, these conditions represent actual brake tests for our vehicles. A more complete list is included in Attachment I.

Each brake system is thoroughly tested to assure that these stringent requirements are met. This testing process involves hundreds of thousands of test miles on hundreds of vehicles. It involves years of fleet testing on public roads as well as scores of tests by Proving Ground testers. This testing is required to satisfy the safety and performance requirements of our customers. As a manufacturer, we provide this level of performance for both OEM and service brake parts for each of these approximately 200 brake systems. Because this process can require up to five years, an abrupt change of the linings on these brake systems can not be made.

As part of its normal product improvement process, GM completes this validation process on about ten new brake systems each year. This process requires about 100 engineers, technicians, and designers dedicated solely to brake system work. In addition, several hundred drivers and testers are required for the road testing of these vehicles. Fortunately, much of the test driving is done on vehicles which have many other parts being tested. However, redesign of vehicle brake systems already in production would require this testing to occur on many vehicles dedicated solely to brake system testing. Thus, if it takes 400 people to validate 10 brake systems per year, it would require an additional 1600 people for five years to redesign and validate 200 existing brake systems. Certainly some economy of scale would reduce this army, but you can see that the effort is formidable. Even neglecting the cost of such an effort, there are not enough trained people to handle an engineering and testing effort of this size.

We have attempted to produce an orderly phaseout of asbestos in the past. In 1979 the GM brake community made it a goal to eliminate asbestos by 1985. This commitment has largely been met on front disk brakes but has not been met on rear drum brakes. The difficulties in changing the rears have been varied and subtle. They include squeal, wear, and friction stability.

In order to completely eliminate asbestos in brake linings, manufacturers, customers and the NHTSA may have to accept some changes in brake performance. For example, if we convince our customers to accept frequent lining changes and periodic replacement of drums, we could probably use some of the non-asbestos European linings. There is a high probability, however, that the customer will tire of the squealing noise and replace his linings with some untested but quiet lining material.

The key point that needs to be made is that even though there are replacements for asbestos, there are no direct substitutes for asbestos. The distinction is that replacement of asbestos linings with non-asbestos linings requires redesign and revalidation of the complete brake system. There are simply no known materials which can be substituted for asbestos with no change in performance. For example, in Attachment II, I have included a list of system changes which might result from a lining change.

In short, the elimination of asbestos friction materials in passenger cars and trucks represents a formidable engineering challenge requiring not only innovation but also invention. As an engineer I can accept that challenge, but only if the timeframe to implement it is realistic, and the process allows a realistic allocation of resources.

ATTACHMENT I

BRAKE TESTING CONDUCTED AT GENERAL MOTORS

Brake System Testing Required by Federal Law

"green" brakes
driver only stopping distances
fully laden stopping distances
fade
water recovery
parking brake
abuse
failures

Brake System Testing Required by Customer Performace Expectations
All of the above testing plus:

durability
corrosion
mountains
noise
hills
fade
vibration
pulsation
cold
snow
car wash
hot
mud intrusion
brake balance
stability
modulation
pedal feel
pull
braking in a turn
wear
service
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ATTACHMENT II

EXAMPLE OF SYSTEM CHANGES THAT MIGHT OCCUR WITH A LINING CHANGE

Assume that a replacement lining has 20 percent less friction than the original:

A larger wheel cylinder would be specified to achieve the required torque output.

A larger wheel cylinder results in more fluid displacement and may require a master cylinder change to obtain the proper pedal travel.

Larger master cylinder may make pedal effort too high necessitating a booster change.

Testing of the vehicle may indicate insufficient park brake capability due to the reduced friction necessitating a park brake cable change.

Increased cable forces may result in park brake strut buckling during abuse tests, necessitating a foundation brake redesign.

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General Motors Corporation
Statement on
EPA Proposed Asbestos Mining and Import Restrictions and
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July 16, 1986

Closing Remarks at Public Hearing on Asbestos Ban by
Joseph P. Chu, Ph.D., P.E.
Assistant Director, Plant Environment
General Motors Environmental Activities Staff

In closing General Motors' statements, I would like to summarize briefly our comments and add some remarks of my own.

I personally believe that, depending upon exposure conditions, any substance may be hazardous and may pose an unacceptable risk to public health and the environment. For example, cyanide is an important industrial chemical which is safe when managed properly. However, when ingested by humans at certain doses, death will occur almost instantly. Similarly, even though water is essential for human survival, a person may die of drowning due to the lack of oxygen caused by an excess quantity of water. Consequently, we ought not propose to ban every substance which is capable of causing harm in order to attempt to create a risk-free society.

In addressing this set of proposed regulations under Section 6 of TSCA, General Motors agrees that asbestos can be hazardous under certain conditions and may pose risk when improperly managed. Therefore, we believe asbestos must be handled with due respect to prevent it from causing any unreasonable risk to public health and the environment.

General Motors objects to the proposed regulations because we do not believe the Administrator has a reasonable basis to conclude that the proposed regulations are necessary. It is important to note that Section 6 of TSCA states:

> "If the Administrator finds that there is a reasonable basis to conclude that the manufacture, processing, distribution in commerce, use, or disposal of a chemical substance or mixture, or that any combination of such activities, presents or will present an unreasonable risk of injury to health or the environment, the Administrator shall by rule apply one or more of the following requirements to such substance or mixture to the extent necessary to protect adequately against such risk using the least burdensome requirements: ......"

We believe EPA did not provide a reasonable basis to conclude that all of the to-be-regulated activities presents an unreasonable risk of injury to health or the environment should the current conditions continue.

As a result of increasingly stringent federal regulations of asbestos for the past 15 years, worker exposure to asbestos has been significantly reduced . In addition, asbestos uses in the U.S. have decreased from about 770,000 tons per year for 1971 to about 240,000 tons per year for 1984. It is beyond doubt that fewer people are exposed to asbestos today and such exposures are at much lower levels than in the past.

The basic problem with this proposal is EPA's use of historical risk and injury information that is related to the consequences of uncontrolled, excessive exposures to friable asbestos. This information is of little relevance to the regulation of manufacturing and use of other types of products which produce minimal exposure.

The chrysotile we use is in a friable form only prior to being manufactured into our brake linings. Our manufacturing facilities are stringently controlled for worker protection and emission prevention. The final products contain chrysotile only in non-friable forms. The use, servicing, and final disposal of these products release virtually no friable chrysotile and pose no significant exposure problems.

Reading the statutory language that I quoted previously, General Motors' objection to the proposed regulations is also related to the permit requirements which are not in line with the statutorily mandated "least burdensome requirements."

Under the EPA proposed 10-year phase-down, the mining and importation permit program will last 10 years. This proposed program would affect GM as an importer. I will discuss the burdensome nature of the proposal, based on my experience with some existing EPA permit programs.

In the proposed asbestos ban regulations, Section 763.148 concerns "Issuance of Permits." It would result in the preparation of permit applications by miners and importers, as well as the review, approval, and tracking of permit applications and approvals by EPA. Similar with other permit programs, obviously there will be frequent phone calls and written communications among applicants, EPA, and their consultants and contractors. And there will be unnecessary actions caused by misunderstanding and confusion.

Other proposed permitting requirements, especially when viewed as a whole, are also burdendome, because they include appeals on EPA's decisions, transfer of permits, banking of permits, reporting requirements, enforcement of the permit program, and EPA inspections to verify permit requirements. Each of these requirements will impose burdensome paperwork and administrative efforts on the part of EPA and regulated parties.

We are also very concerned that the 70% reduction in the supply as required by the proposed regulation may not allow General Motors to provide chrysotile containing brake parts for OEM or servicing our customers' existing vehicles.

We believe EPA, in proposing this set of regulations, has incorrectly assumed that asbestos containing parts and non-asbestos containing parts are interchangable regardless of the design of brake systems. We must point out that any automotive brake system can safely be used only with parts which were designed for it.

As we pointed out previously, General Motors has developed and put into use brake systems that do not use asbestos. Our development of new brake systems and new material applications continues. However, we cannot predict when we can invent and when new materials will be discovered or developed which will permit us to use non-asbestos parts in <u>all</u> of our brake systems. This is especially true for heavy duty trucks.

Therefore, considering the safety of our customers and the the general public, we are obligated to continue production of chrysotile containing parts for servicing vehicles requiring such parts throughout their useful life. In addition, as we have pointed out, the current health risk of asbestos in motor vehicle applications, contrary to EPA's estimate, is insignificant.

General Motors does not believe there is a need for the EPA proposed phaseout of asbestos. If the EPA acts, however, General Motors recommends that a ban on asbestos friction materials for motor vehicles not take effect until after a period of ten years; and, that the EPA permanently exempt aftermarket brake linings. The details of these and other General Motors recommendations have been previously submitted in our written comments.

This concludes our remarks. We would be pleased to answer any questions the panel might have.

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Statement on
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July 16, 1986

Statement for Public Hearing on Asbestos Ban by
William H. Krebs, Ph.D.
Director, Toxic Materials Control Activity

I welcome the opportunity to comment on EPA's analysis of the health effects of asbestos as it relates to General Motors use of asbestos-containing friction materials.

The exposure of workers to excessive concentrations of airborne asbestos has long been recognized as an occupational hazard of industrial health significance. Where excessive exposures occur, it is generally recognized that inhalation of asbestos dust causes chronic inflammation of lung tissue and pleural membranes, as well as cancers. Ambient atmospheric levels of asbestos are not a recognized hazard to the public.

All types of asbestos are known to cause the inflammatory changes in the lungs and pleura and lung cancer. However, there is anecdotal, experimental and epidemiological evidence that there are differences in the potential of the different asbestos types to produce disease. Crocidolite is reported to have the greatest potential; amosite in between; and chrysotile being the least.

Of particular interest, and a reason behind the introduction of new regulations, is the relationship between the inhalation of asbestos and cancer, especially mesothelioma. The association between mesothelioma and asbestos first was demonstrated by Wagner et al in 1960. Mesotheliomas are rare, usually rapid, fatal cancers that originate from the surfaces lining the chest or abdominal cavity. From 1960 through 1975, 4,539 mesotheliomas were reported worldwide. Where asbestos exposures were involved, the vast majority of these cancers were in people exposed to crocidolite alone or in combination with other types of asbestos. Importantly, crocidolite, is not a component of brake lining materials.

Furthermore, not all mesotheliomas result from asbestos exposure. According to the American Conference of Governmental Industrial Hygienists, there is a background of spontaneously occurring mesotheliomas that has been estimated to be about ten (10) for males per million people and four (4) for females aged 45 years and older per million people. It is not uncommon for various epidemiologic studies to indicate that 15% or more of the reported mesothelioma cases have no history of ever having been exposed to asbestos.

Whether there is a dose response relationship associated with asbestos has been answered affirmatively by a number of epidemiologic studies. It is clear cut with regard to asbestosis and lung cancer. It is less well established with mesothelioma, but it is nonetheless positive. The existence of a threshold exposure level is not universally agreed upon. However, industrial hygienists, after careful study, have agreed that a threshold concept is consistent with their professional experiences and observations. As Dr. John Higginson once said, and I paraphrase, "For all intents and purposes, asbestos has a practical threshold when one takes into account its biological potency."

Of particular interest is the importance of the biological consequences of fiber morphology and size. Initially, a size limitation was placed on fibers being counted when using the National Institute for Occupational Safety and Health phase contrast method for asbestos. This was done because it was not practical to count shorter fibers with an optical microscope. It is recognized that for every fiber longer than 5 micrometers, there may be many more which are shorter that are not visible. However, there now is considerable experimental evidence to indicate that asbestos fibers shorter than 5 micrometers are not pathogenic. This has important environmental implications.

In the manufacture of friction materials, employe exposures are regulated by the Occupation Safety and Health Administration's Asbestos Standard. In the recent OSHA asbestos rulemaking, many of the studies relied upon by EPA for the ban and phaseout rule were also considered by OSHA. As you know, OSHA adopted practices that allow the controlled use of asbestos while EPA is proposing the material be banned. From the environmental viewpoint, the nature and extent of exposures to airborne levels of brake wear debris to which the public or employes may be exposed is not sufficient to result in disease. Furthermore, exposure to brake wear debris has not been shown by any reliable studies to cause any asbestos-related disease.

Brake linings contain approximately 50% asbestos by weight, all of which is chrysotile. Not only is chrysotile less hazardous than other asbestos types, but in friction materials chrysotile fibers are encapsulated in a solid resin matrix. During the braking process more than 99% of the asbestos fibers by weight in the brake lining mix are transformed into a non-asbestos material, reported by some to be forsterite. Furthermore, most brake wear debris is removed from the brake drum during vehicle operation. Industry studies confirmed by the EPA have shown that the brake debris which was present in the drums at the time of the brake service work contains less than 1% free asbestos by weight. Moreover, the asbestos fibers which were found in the brake wear debris are predominantly submicroscopic. As previously discussed, reliable studies have shown that, generally speaking, only longer asbestos fibers (greater than 5 micrometers in length) result in asbestos-related diseases.

Asbestos-related diseases are known to be dose-related. That is, there must be exposure to respirable asbestos fibers in excessive amounts for sufficient time before an adverse health effect will occur in some of the exposed personnel. There are well accepted exposure standards to which the results of air tests can be compared. These standards are used by the federal and state governments, and represent the concentrations to which employes can be repeatedly exposed, 8 hours per day, 5 days per week, year after year, without experiencing an adverse health effect. Studies of brake servicing operations have shown that the level of exposure to asbestos resulting from such work is well within the accepted exposure range.

My own industrial hygiene air studies conducted in dealership service garages have shown that asbestos exposure from brake wear debris was well below exposure limits in use at the time of the studies and well below exposure limits about to go into effect. The exposure to asbestos of mechanics who regularly perform brake work is of an intermittent nature. These findings have been verified by analysis of industrial hygiene studies conducted by NIOSH.

Brake relining operations were first identified as a <u>possible</u> source of potential excessive exposure to asbestos in reports published in the mid-1970's. Since that time, however, my own studies, as well as reliable reports appearing in literature, have shown that the studies on which the 1974 opinions were based are in error. Even though brakewear debris is known to contain a very minute percentage of asbestos fibers, no asbestos-related disease was found in studies in which animals were administered heavy doses of brake wear debris, and there is no study showing an excess of any asbestos-related disease among mechanics.

Substitute materials for asbestos have unknown toxicological properties. Given the long latency for the pneumoconiosis producing dusts, the introduction of new durable fibrous materials by producers gives the appearance they are "safer" than asbestos. Eventually that may prove to be true, but given the scientific evidence that is available today, General Motors believes that many of the durable fibers which EPA is suggesting be considered as replacement materials have not been studied sufficiently by their manufacturers to assess their safety or to draw comparisons with asbestos.

Suppliers have just begun to initiate experimental studies with a few of these materials. What appears to be occurring is a national movement from regulated to unregulated materials to avoid, among other things, the cost of compliance with workplace controls. This potentially could have tragic consequences. Given the fact that several asbestos substitute materials that were declared safe by EPA have later become the subject of Section 8(e) submissions, General Motors has adopted the following guideline. Until sufficient data are obtained, GM will continue using the environmental controls for asbestos when using substitute durable fibers.

In summary, exposure to asbestos received by the public and employes as a result of exposure to brake relining operations and normal braking operations, are minimal and far below the levels of exposure necessary to cause asbestos-related disease.

Because of the extremely low levels of submicroscopic asbestos present in brake wear debris and the intermittent nature of the exposure involved in brake relining aberrations, it is my opinion that asbestos brake lining and brake relining operations do not present a risk of adverse health consequences to those involved.

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Statement of the

Motor Vehicle Manufacturers Association

of the United States, Inc.

on the

Notice of Proposed Rulemaking

ASBESTOS; PROPOSED MINING AND IMPORT
RESTRICTIONS AND PROPOSED MANUFACTURING,
IMPORTATION, AND PROCESSING PROHIBITIONS

DOCKET NO. OPTS-62036

(40 CFR Part 763)

ENVIRONMENTAL PROTECTION AGENCY

Presented Before the
United States Environmental Protection Agency Hearing
Washington, D. C.
July 24, 1986

My name is Fred Bowditch. I am Vice President for Technical Affairs at the Motor Vehicle Manufacturers Association of the United States, Inc., (MVMA).* MVMA appreciates the opportunity to comment on EPA Docket OPTS-62036 Proposing Restrictions on Products Containing Asbestos. The Association filed comprehensive comments on this proposed rulemaking on June 29, 1986.

Today, I will only address the following topics: substitutes for asbestos used in motor vehicle friction applications, the proposed permit and phase-down system, asbestos substitutes for in-service vehicles and labeling of asbestos-containing automotive products.

The predominant use of asbestos in motor vehicles today is in brake linings. In many vehicles, the use of asbestos for brake systems is necessary to achieve an essential blend of strength, friction stability, and temperature capability. In the past several years, motor vehicle manufacturers have developed non-asbestos substitutes for certain applications but, unfortunately, those substitute friction materials cannot be used in all brake systems. Today, most motor vehicles still must use asbestos friction materials because no substitute, to date, has been found that can directly replace asbestos for all motor vehicle friction applications. Vehicle manufacturers are involved in continuing research and development for alternative materials acceptable for motor vehicle applications. This effort has produced varying degrees of success.

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* MVMA members are: American Motors Corporation; Chrysler Corporation; Ford Motor Company; General Motors Corporation; Honda of America Mfg., Inc.; LTV Aerospace & Defense Company, AM General Division; M.A.N. Truck & Bus Corporation; Navistar International Corporation; PACCAR Inc; Volkswagen of America, Inc.; and Volvo North America Corporation.

The phase-down schedule in the permit system EPA proposes fails to recognize that time is needed to develop non-asbestos substitutes which will not compromise the performance of brake systems. The proposed phase-down schedule calls for an immediate 70 percent reduction of asbestos usage. Given that this phase-down schedule could begin in as short a time as four months and one day after rule promulgation, motor vehicle manufacturers are essentially being told that they have 121 days to invent non-asbestos substitute friction materials to test those materials to be sure that it meets all Federally mandated performance requirements as well as all customer-acceptance criteria, and to have that material in production to substitute for 70 percent of the asbestos applications in the vehicles they manufacture. This is simply not enough time. The amount of time required to accomplish the task will vary among vehicle manufacturers. Undoubtedly, specific leadtime requirements have been addressed in the comments filed by individual vehicle manufacturers in this proceeding.

MVMA also calls attention of the Agency to the fact that the baseline years for calculating permit credits would encompass a period when the level of motor vehicle production in the U. S. was significantly depressed by the severe downturn in the economy. The baseline amount of asbestos allowed for the automotive industry, therefore, would be artificially low by some 25 percent. Further, that baseline period cannot be compared with the present situation. U. S. automakers are now importing more foreign-built motor vehicles than ever before. Most of these imported vehicles contain asbestos parts. MVMA believes the choice of a baseline period with uncharacteristically low domestic vehicle production and which ignores industry-wide change in vehicle import pattern since the baseline period, would force the automotive industry to eliminate asbestos at a rate that is even more drastic than might be suggested by the percentage figures required by the proposed rule.

The choice of the baseline years and the proposed rate of asbestos elimination are not the only problems with the proposed permit system. MVMA believes that the Agency has underestimated the burden and complexity of permit acquisition, recordkeeping, and reporting in the case of the automotive applications. Not all American motor vehicles today are assembled completely within the U. S. Components and sub-assemblies that may contain asbestos are produced in many countries, assembled into complete vehicles in other countries, and some are finally sold in the U. S.

Bulk asbestos is also imported into the U. S. to be used in components and sub-assemblies. Those parts are then exported to other countries to be assembled into complete vehicles that are eventually re-imported into the U. S. The recordkeeping associated with this importing, exporting, and re-importing of asbestos, asbestos-containing vehicle parts and asbestos-containing vehicles would be a complex, enormous and burdensome task for the automotive industry and for those Department of Treasury Customs Service personnel who would be engaged in monitoring cross border movements of asbestos and asbestos-containing products. This recordkeeping and reporting would not only tax industry and government resources and add unnecessary costs to consumers, but would not result in any benefits.

EPA has asked for comments on whether aftermarket brake linings that contain asbestos should be required to be replaced with non-asbestos substitutes. MVMA believes that a blanket substitution of non-asbestos friction materials in the aftermarket would ignore the critical importance of friction material to proper performance of the brake system. The magnitude of the engineering task to ensure that adequate brake performance is maintained for those vehicles is underestimated by the Agency. Each in-service brake system design would have to be evaluated to determine the effect of each asbestos substitute on brake performance. In most cases re-engineering would be required. For example, components such as proportioning valves and wheel cylinders may require changes to produce the correct system pressures to maintain braking forces with the substitute material.

If EPA promulgates any regulation involving the ban of asbestos friction products, the Agency must provide means to avoid compromises to in-service brake performance. Exemption procedures must be in place to allow use of asbestos material in brake systems where no adequate replacement parts are available. There must be an immediate exemption process so that vehicles having brake systems which were originally designed to use asbestos friction materials could continue to be serviced with similar materials.

The exemption process must, of course, also include provisions for exempting the original equipment applications for which non-asbestos substitutes cannot currently be identified. MVMA strongly urges the Agency to establish procedures for obtaining exemptions before the promulgation of any rule. These procedures should be proposed in a supplementary rulemaking notice.

On the question of whether the labeling of asbestos-containing parts on motor vehicles would further reduce the risk of exposure to asbestos, MVMA believes that the current voluntary labeling practices of MVMA members are sufficient and that further labeling requirements would be neither cost-effective nor necessary. If EPA persists with a labeling requirement, MVMA urges the Agency to propose specific details regarding the requirements and provide an opportunity for comment.

EPA should coordinate its consideration of asbestos elimination with the National Highway Traffic Safety Administration to ensure that one perceived health issue is not addressed at the expense of another--traffic deaths and injuries.

In summary:

There is no single asbestos substitute material for all automotive friction applications.

The proposed permit system and phase-down are unfairly based, and so burdensome as to be unworkable.

Blanket substitution for asbestos in vehicles already on the road may adversely affect their brake performance.

Labeling requirements beyond the current voluntary practices of vehicle manufacturers are unnecessary.

Thank you.

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November 29, 1984

BY HAND

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Dear Dr. Moore and Mr. Barnes:

This letter, submitted on behalf of our client, the Asbestos Information Association/North America (AIA/NA), supplements our earlier letters and calls to your attention further developments since we met with you and Deputy Administrator Alm last spring. As we show, these developments, including the recently completed proceedings before OSHA, hearings before the EPA Science Advisory Board, and actions by governments around the world, argue persuasively against banning asbestos products or imposing a regulatory cap on domestic asbestos use under the Toxic Substances Control Act (TSCA). The appropriate course is to regulate asbestos stringently in the workplace and in commerce so that it can be safely used by the public.

A. The International Regulatory Community Has Again Reaffirmed the Consensus Against Banning and in Favor of Safe Use of Asbestos.

As detailed in our March 22, 1984 letter, experts as diverse as the International Labor Organization (ILO), Irving Selikoff of Mount Sinai Medical School, and the European Economic Commission have all concluded banning asbestos is not only unnecessary but also very likely counter-productive given the potential health risks posed by uncontrolled asbestos substitutes. Since EPA's ban and phase-out plans have become more widely known, international opposition has become more pronounced.

Following receipt of diplomatic notes opposing EPA's ban plans from the European Economic Community, Austria, Belgium, Canada, the Federal Republic of Germany, Mexico, Switzerland, and the United Kingdom, the Agency conducted a poll through the State Department to determine whether any nation supported its plans. Only Denmark of all the responding nations supported the EPA approach.1/ In contrast to the U.S., however, Denmark has established an all-fiber regulatory standard to assure that substitute fibers are closely controlled. In the absence of comparable regulatory controls in this country, banning asbestos would encourage uncontrolled, and potentially more dangerous, exposures to alternative fibrous materials.

Significantly, the U.S. Department of Labor recently joined the many nations who have concluded that asbestos product bans are unwarranted. In Labor's official comments to an ILO questionnaire on asbestos, the Department noted its concern about the safety of substitute materials:2/

1/ *See* "Inside EPA," at 5 (Aug. 31, 1984).

2/ Letter to the ILO Environmental Department from Department of Labor Deputy Under Secretary Robert W. Searby, Att. I, at 2-3 (Oct. 29, 1984). The AFL-CIO's comments to the ILO agree that any "[a]ctions to require or encourage the substitution of asbestos must include a full evaluation of the toxicity of the substitute materials and regulation of these materials as necessary." *Id.*, Att. 3, at 4.

> While continued use of asbestos may be curtailed where suitable substitutes are available, it should still be recognized that with appropriate protective measures asbestos is still a valuable resource. With regard to the replacement or substitution of asbestos by "harmless or less harmful substances," it should not be presumed that any substitute will be "harmless or less harmful." Rather, each potential substitute should be thoroughly evaluated.

Consistent with the international consensus, until "each potential substitute" has been "thoroughly evaluated", it would be precipitous and potentially counterproductive for EPA to ban or phase out asbestos use. This is especially true given the fact that the worker health concerns that originally gave rise to EPA's TSCA intentions will soon be substantially ameliorated by revised OSHA standards.

B. The Recently-Completed OSHA Proceedings Will Lead to Safer Workplace and Construction Industry Use of Asbestos.

Our March 22 letter summarized the OSHA proceedings then getting underway to tighten workplace control of asbestos use not only in manufacturing, but also in downstream fabrication, installation and use of asbestos-containing products, including construction, abatement and demolition activities. OSHA has since proposed reducing the permissible exposure limit from 2.0 to either 0.5 or 0.2 fibers/cc, imposing much more effective respirator requirements, and developing a separate standard for the construction industry, where the vast majority of asbestos exposures occur. 49 Fed. Reg. 14116 (April 10, 1984). The Agency held a three-week hearing in June and July during which more than 100 witnesses appeared and has compiled a massive evidentiary record on all aspects of asbestos control.

A major focus of discussion in the hearings was OSHA's asbestos hazard assessment, a document that EPA has referred to over the past year to justify its concerns about asbestos.3/ Each of the peer reviewers of this document expressed various concerns that it overestimated likely worker risks. These concerns are summarized in AIA/NA's OSHA post-hearing brief (pp. I-1 to I-34), copies of which are enclosed for your consideration.

Essentially the same types of concerns with OSHA's asbestos health assessment were recently voiced by EPA's own Science Advisory Board which had been called upon to consider an asbestos health update written for the Air Office by the same William Nicholson who authored the OSHA risk assessment.4/ Like witnesses in the OSHA proceedings, the SAB Panel had doubts about Dr. Nicholson's approach and expressed concern that the many uncertainties involved must

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3/ *See*, *e.g.*, letter from John A. Moore to Edward W. Warren (April 12, 1984).

4/ During that review, SAB member Dr. Morton Corn, who had appeared at the OSHA hearings for the AFL-CIO, noted that the "uncertainty" in Dr. Nicholson's risk assessments needed to be "put ... in perspective" as had been "clear[ly]" and "excellent[ly]" accomplished by the critique presented at the OSHA hearings by Dr. Kenny S. Crump. SAB Tr. at 131 (July 24-25, 1984). Dr. Crump, who has authored all recent OSHA risk assessments other than the asbestos assessment, concluded that in many respects OSHA had significantly overestimated likely risks. Many of those defects were also identified in the SAB Environmental Health Committee's letter to William D. Ruckelshaus from Herschel E. Griffin and Norton Nelson (October 29, 1984) (*e.g.*, failure to consider fiber type differences, inappropriate evaluation of exposure data, finding associations for other than lung cancer and mesothelioma, insistence on a linear dose-response relationship).

be fully explicated before any such document becomes the basis for EPA regulatory action. At a minimum, these concerns underscore the need for EPA to satisfy its statutory duty of submitting any asbestos assessments underlying its TSCA plans to the SAB for "advice and comment" before publishing its ban and phase-out proposals.5/

AIA/NA was an active participant in the OSHA hearings and suggested to that Agency a comprehensive program to lower permissible exposures to the maximum extent feasible. *See* AIA/NA Br. at 1-4. AIA/NA has recommended that OSHA provide workers with the wherewithal to employ respirators to reduce exposures even further, and to require aggressive actions to end smoking among asbestos workers. *Id.* at III-1 to III-11, III-25 to III-26. Those actions would reduce lifetime cancer risks for the typical asbestos worker to less than 1/20,000 even if OSHA's exaggerated hazard assessment were accepted. Far lower risks would be predicted were the estimates based on a more balanced asbestos risk assessment of the type called for by the Science Advisory Board. *Id.* at I-28 to I-32.

OSHA's regulatory calendar calls for issuance of a revised asbestos standard in March 1985. 49 Fed. Reg. 41845 (Oct. 22, 1984). By that time, any remaining doubts that asbestos exposures can be reduced to levels well within an acceptable range should be resolved. The record in the OSHA hearings has provided ample basis to issue the most protective OSHA health standard ever developed for any carcinogen

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5/ The Environmental Research, Development, and Demonstration Authorization Act of 1978, 42 U.S.C. § 4365(e), requires that the "Administrator, at any time any proposed...regulation under the...Toxic Substances Control Act...is provided to any other Federal agency for formal review and comment, shall make available to the [Science Advisory] Board such proposed...regulation, together with relevant scientific and technical information."

-- a standard that lowers risks to well within the range EPA has often considered too small to merit regulation.6/

The likelihood that a comprehensive new OSHA asbestos standard will be in place shortly reaffirms Congress' wisdom that EPA should not replace OSHA as a workplace regulator. Although it might once have been appropriate for EPA to refer its occupational concerns to OSHA under TSCA Section 9, OSHA's own actions have made such referral unnecessary. To the extent there may exist occupational or other exposures that will not be reached by the revised OSHA standard, EPA should consider, following issuance of OSHA's final standard, whether or not further "gap-filling" measures might be advisable under TSCA. AIA/NA would welcome the opportunity to participate in any discussions of those questions.

C. AIA/NA Stands Ready, as Always, to Resume the 1982 Discussions, Designed to Identify Gaps in Asbestos Regulation.

As we discussed in our meetings with you and Deputy Administrator Alm last spring, AIA/NA has long supported development of reasonable regulations to assure safe use of asbestos. The Association and its members met on numerous occasions in 1980 and 1981 with EPA's staff to

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6/ As we have noted in our letters to you of March 22 and May 14, 1984, even OSHA's exaggerated risk assessment would predict few cancer cases over the next 50 years from manufacture and installation of asbestos-cement pipe -- the major product EPA has indicated it intends to ban. Given the very low exposures in such operations, the OSHA risk estimate would predict but one excess cancer death every 20 years -- a risk well within the range EPA has just recently found not worthy of regulation in its radionuclides decisions. 49 Fed. Reg. 43906, 43911-13 (Oct. 31, 1984).

identify whether and how TSCA initiatives might be useful in this effort. With the issuance of a comprehensive new OSHA standard expected shortly, now is an ideal time to recommence those discussions.

In 1982, EPA also was properly focusing its attention on identifying gaps in the government's regulatory control of asbestos. When issuing a TSCA Section 8(a) information collection rule, the Agency declared it was interested in "establish[ing] agreements, as appropriate, for industry to take voluntary steps to reduce the levels of risk," "examin[ing] the various Federal statutes to find the most appropriate authority to effect the necessary control," and "determin[ing whether] labelling of products would sufficiently reduce the risk." 47 Fed. Reg. 33197, 33198-99 (July 30, 1982). OSHA's activities to address all aspects of occupational exposures, EPA's own on-going reassessment of Clean Air Act regulations, and the continuing attention in the Office of Toxic Substances to asbestos in schools all are in accord with the approach EPA outlined in 1982. Likewise, they are in keeping with the international consensus for strict control, but not ban, of asbestos.

Rather than continuing to press for the issuance of ban and phase-out proposals that may be counterproductive from a public health standpoint, AIA/NA urges that EPA recommence the dialogue that was on-going in 1982. The information the Agency collected under its Section 8(a) rule, the comprehensive record now compiled at OSHA, and the work being done by the Air Office, all should be of use in identifying practical measures to regulate specific uses of asbestos. Moreover, AIA/NA would welcome the participation of other interested parties including other regulatory agencies, labor unions and environmental groups who have indicated interest in asbestos regulation.

If it would be helpful, AIA/NA would welcome the opportunity for an industry delegation to meet with you and your staff to discuss any of the matters discussed in this letter.

Sincerely,

Edward W. Warren p.c.

Edward W. Warren, P.C.

Enclosures

cc w/o encs: Don R. Clay
Joseph De Santis

~~Encl 6~~ 2

GMC

N1-007a(03)02

62036

N1-7a(3)2

April 17, 1985

Ms. Margaret Stasikowski
Director of Chemical Control Division
Office of Toxic Substances
U. S. Environmental Protection Agency, Room E-513
410 M Street, SW
Washington, DC 20460

Reference: OPTS-211015

Dear Ms. Stasikowski:

Attached is the General Motors Corporation (GM) statement on the referenced matter: Asbestos; Response to Citizens' Petition.

Since the issue of asbestos substitutes in motor vehicle brake systems is highly complex, technical representatives from General Motors would be pleased to meet with the Agency's technical work group to discuss the issue in detail. Please contact me at GM's Washington, D.C. office or call (202) 775-5082, to arrange such a meeting.

Thank you for the opportunity to comment on this issue.

Sincerely,

W. C. Chapman
Director,
Washington Office

Att.

cc: Public Information Officer (TS-793)
OPTS-211015

1714

LOG

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

NN3- 05

62036

MAR 9 1988

NN3-5

OFFICE OF
PESTICIDES AND TOXIC SUBSTANCES

MEMORANDUM

SUBJECT: Meeting with Representatives of Ibiden Co., Ltd.

FROM: John Rigby JR
Chemical Control Division

Substitutes

TO: The Record

On March 8, 1988, John Rigby and Lynda Priddy of the Chemical Control Division and Kathleen Gaaserud of the Office of International Activities met with Hidetoshi Yamauchi and Hideyo Kawase of Ibiden Co., Ltd. and Hirotami Makimura of Mitsui & Co. (U.S.A.), Inc. Mr. Rigby and Ms. Priddy discussed the status of the asbestos ban and phaseout rulemaking, the availability and identity of substitutes for certain asbestos uses, and the use of ceramic fibers in the United States.

The attached material was given to the EPA representatives at the meeting.

Attachment

Rec'd

ASBESTOS DEMAND IN JAPAN

(X1000t , %)

	1982		1985		1986	
Asbestos Cement Materials	152.2	68.0%	154.1	70.9%	148.9	73.2%
Textiles	8.5	3.8%	7.3	3.3%	5.2	2.5%
Packings	8.1	3.6%	8.2	3.8%	7.3	3.6%
Friction Products	15.7	.7.0%	17.6	8.1%	17.7	8.7%
Papers, Board etc	21.3	9.5%	15.9	7.3%	12.3	6.1%
The Others	18.0	8.1%	14.3	6.6%	12.0	5.9%
Total	223.8	100.0%	217.4	100.0%	203.4	100.0%
Import	229.1		261.6		255.7	

62035

NN4-15

NN4-15

2954

TSCA PHONE CALL LOG*

Project: Asbestos (EPA 42-321)

Name of ICF Caller: Wendy Roberts

Organization Contacted: Bendix Corporation

Location: Troy/Green Island, NY

Name of Person Contacted: Tom Buchanan/Harold Scott (Personnel)

Position of Person Contacted: Marketing/Sales

Phone Number: (518) 270-0200

Date/Time of Contact: 10/4/88, 9:30 a.m.

Questions/Responses:

Mr. Buchanan stated that there is still a demand for asbestos products in the aftermarket, although there are very few requests for the OEM. He also said that their research department is continuing to develop semi-metallic and NAO substitutes because brake linings must be designed to fit the specific weight distributions of each car or truck.

As for performance data on the substitute materials, he said that he would check with an engineer -- he thought they had some data. However, he said that the substitutes do not work as well as asbestos and the costs have doubled.

On October 6, 1988 (9:30 a.m.) -- Mr. Buchanan referred me to their public relations person (Harold Scott) who will call today.

On October 6, 1988 (12:00 noon) -- Mr. Scott called. He said he would send any available information to EPA.

Recd 10/14/88

* To be maintained in permanent file.

62036

NN4-16

NN4-16

2449

TSCA PHONE CALL LOG*

Project: Asbestos (EPA 42-321)

Name of ICF Caller: Wendy Roberts

Organization Contacted: Carlisle

Location: Ridgeway, PA

Name of Person Contacted: Bob Tami

Position of Person Contacted: ____________

Phone Number: (814) 773-3185

Date/Time of Contact: 10/4/88, 11:00 a.m.

Questions/Responses:

Mr. Tami said that Carlisle has developed a product line of non-asbestos products. Most of the substitutes use Kevlar or mineral fibers. He is sending product literature and test data on these products.

Carlisle stopped making all asbestos products in July, 1986.

10/14/88 [illegible]

* To be maintained in permanent file.

2451

62036
NN4-17
NN4-17

TSCA PHONE CALL LOG*

Project: Asbestos (EPA 42-321)

Name of ICF Caller: Wendy Roberts

Organization Contacted: Standco Industries

Location: Houston, TX

Name of Person Contacted: A.C. Dulaney

Position of Person Contacted: ______

Phone Number: (713) 224-6311

Date/Time of Contact: 10/4/88, 12:00 noon

Questions/Responses:

Mr. Dulaney said that Standco has developed an asbestos-substitute product for molded brake linings for both the OEM and aftermarket. However, they do not have a woven non-asbestos lining, so that the company still manufactures some asbestos brake products.

He requested a letter formalizing ICF's request for information. This letter was sent on October 4, 1988.

Rec'd 10/14/88

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* To be maintained in permanent file.

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2450

NN 4-18

NN4-18

TSCA PHONE CALL LOG*

Project: Asbestos (EPA 42-321)

Name of ICF Caller: Wendy Roberts

Organization Contacted: Lear Steigler Corporation

Location: Danville, KY

Name of Person Contacted: ______________

Position of Person Contacted: ______________

Phone Number: ______________

Date/Time of Contact: 10/5/88

Questions/Responses:

We were unable to determine a phone number for this corporation. Directory assistance in Kentucky has no listing for the Lear Steigler Corporation and the 1988 Corporate Affiliations Directory has no listing for a brake manufacturing division or subsidiary of Lear Steigler.

Rec'd 10/14/88

* To be maintained in permanent file.

24568

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NN4-20

NN4-20

TSCA PHONE CALL LOG*

Project: Asbestos Brakes (02307-318)

Name of ICF Caller: Mark Wagner

Organization Contacted: Carlilse Corporation

Location: Ridgeway, PA

Name of Person Contacted: Bob Tami

Position of Person Contacted: Supervisor, Safety and Health

Phone Number: (804) 773-3185

Date/Time of Contact: 10/10/88, 11:00 a.m.

Questions/Responses:

Mr. Tami stated that Carlilse no longer produces asbestos brake components for the truck and heavy equipment market. They do provide, however, a wide range of substitute brake blocks that can replace asbestos brake blocks. These substitute brake blocks are available for the OEM and aftermarket segments. he stressed that Carlilse has a very diversified non-asbestos product line and that for the market segments that his company targets, there is at least one non-asbestos product that can replace the asbestos products that have been used.

The majority of applications for Carlilse substitute products are brake blocks for heavy trucks, tractors, trailers, earth movers, loaders, transit buses, school buses, delivery vans, and other medium trucks. In addition, Carlilse provides some substitute materials for disc brake pad applications, but to a lesser degree. Mr. Tami feels that the substitute disc brake pad market for trucks will grow rapidly in the near future as fleets begin to translate the experience of the brake block market to lighter trucks. He does not have enough familiarity to speculate with certainty the trend for passenger vehicles, but felt a similar pattern may begin to appear in the near future.

Mr. Tami repeated that the substitute brake blocks that they provide are intended to be replacement brakes for systems previously using asbestos-based products, but that some products were also being specified for the OEM market for certain customers.

The OEM specs are very high for all friction materials and it is important to note that replacement products, asbestos and non-asbestos, often do not meet the OEM specs. The replacement brakes do meet the government

* To be maintained in permanent file.

Rec'd 10/11/88

requirements and do not pose a safety risk. In addition, some Carlilse products have been approved for OEM specs and in fact out-perform the asbestos products that they replace. Brake blocks made from substitute materials work better than asbestos-based products in many cases for two reasons: (1) they last longer (40 to 100 percent longer) and (2) they are not as damaging to other brake components (shoes, brake drums, cam rollers, wheel seals, return springs, and bushings). As braking components are made from lighter, aluminum alloys and other materials to reduce vehicle weight, the lower abrasiveness of substitute brake blocks has become critical.

In summary, Mr. Tami firmly believes that the market for substitute friction materials will continue to grow and that these materials will be more widely accepted in the OEM and aftermarket segments.

2455

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NN4-21

NN4-21

TSCA PHONE CALL LOG*

Project: Asbestos Brakes (02307-318)

Name of ICF Caller: Mark Wagner

Organization Contacted: Abex Corporation

Location: Winchester, VA

Name of Person Contacted: John Shepard

Position of Person Contacted: Research and Development

Phone Number: (703) 662-3871

Date/Time of Contact: 10/11/88, 2:00 p.m.

Questions/Responses:

Mr. Shepard stated that Abex has not manufactured, imported, or distributed asbestos-containing brakes since December 1987. Their position is that non-asbestos products can substitute for asbestos products in the OEM, as well as aftermarket segments without sacrificing braking performance. As long as similar design and performance criteria are used in developing the substitute, it will be able to replace the asbestos product currently in use.

The friction rating is one criterion of brake performance, but not the only one. Quality control standards and assembly procedures also determine actual brake performance. It is important to evaluate all of these factors when designing or testing replacement brakes (i.e., not to rely too heavily on friction performance rating that varies by product and application).

Regarding OEM specs, Mr. Shepard stated that each manufacturer requires certain levels of performance that go beyond essential safety considerations. For example, the manufacturer may require a certain noise rating or that brake pads last 100,000 miles to meet warranty requirements, but these are individual preferences and do not necessarily relate to safety. In the aftermarket, products are often grouped by comparable performance. It would not be practical for each distributor or manufacturer of replacement brake pads to provide a replacement product for each new vehicle specification. The proliferation of aftermarket products, if this were the case, would be infeasible and unnecessary. Mr. Shepard indicated that aftermarket suppliers would not jeopardize safety by standardizing the specs, but must do this to simplify purchasing for the diverse range of OEM products that need to be replaced.

Rec'd 10/11/88

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* To be maintained in permanent file.

For passenger vehicles, there are two categories of friction materials: metallic or semi-metallic, and non-metallic. Within the non-metallic category there are asbestos, and non-asbestos organic (NAO) formulas. For domestic and imported cars and light trucks, the semi-metallic category for disc brake pads is growing and occupies 55-60 percent of the disc brake replacement market. Of the remaining 40-45 percent, there is currently a 50/50 split between asbestos and non-asbestos products with the trend being towards non-asbestos products. Mr. Shepard specifically stated that the substitute products worked well in systems designed to use asbestos and that the trend would continue to be a move away from asbestos products.

Mr. Shepard went on to say that the OEM and aftermarket manufacturers in the U.S. were essentially out of the asbestos market and that imports of asbestos products accounted for a large proportion of asbestos disc brake pads available in the U.S. He felt that EPA should accelerate the restrictions on imports and distribution and that this would help to alleviate what he sees as a problem.

For example, Mr. Shepard stated that he knows of one company that does not make asbestos brake products, but did import them as of a few months ago. That company is strongly against asbestos, but may be pressured into supplying the asbestos products by customers that demand them. Since it is uneconomical or impractical for domestic companies to make asbestos products due to liability and regulatory situations, it seems illogical to allow importation. If importation was restricted, substitutes would replace asbestos even more rapidly.

He does not understand why the U.S. brake companies should be under such great pressure to stop using asbestos for domestic production if importation for the aftermarket is still permissible. This is especially troublesome considering the imported asbestos products are usually low cost materials with low-end performance.

Mr. Shepard will be sending some test data, but for more information please contact him at:

Abex Corporation
Building 20
1827 Powers Ferry Road
Marietta, Georgia 30067
(404) 953-2045

62036

2452

NN4-22

NN4-22

TSCA PHONE CALL LOG*

Project: Asbestos (EPA 42-321)

Name of ICF Caller: Wendy Roberts

Organization Contacted: Raymark Corporation

Location: Marshville, NC

Name of Person Contacted: Lou Williams

Position of Person Contacted:

Phone Number: (704) 624-6031

Date/Time of Contact: 10/11/88

Questions/Responses:

Mr. Williams stated that there are still some asbestos products on the line that contain asbestos. However, he estimated that the North Carolina plant, which makes friction materials, will be fully converted by early next year. This estimation depends on customer requests because many customers still request asbestos-containing products. Mr. Williams remarked that the conversion of the friction products manufactured at the North Carolina plant has gone reasonably smoothly because of the development of a glass and organic substitute material.

He suggested that I call Blaine Lowry of the Manheim, PA plant for performance data.

Recd 10/14/88

* To be maintained in permanent file.

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NN4-27
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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

SEP 8 1988

OFFICE OF
PESTICIDES AND TOXIC SUBSTANCES

MN4-027

MEMORANDUM

SUBJECT: July 12, 1988 Meeting Between EPA and NHTSA

FROM: John Rigby
Chemical Control Division

TO: The Record

On July 12, 1988, officials of the Environmental Protection Agency (EPA) and the National Highway Traffic Safety Administration (NHTSA) met. The group discussed the EPA rulemaking to phase out use of asbestos in friction products and the NHTSA rulemaking to revise brake safety standards. The following persons attended the meeting:

EPA

Office of Toxic Substances

John Melone
John Rigby
Lynda Priddy
Kin Wong
Vinay Kumar
Paul Campanella

Office of Policy and Program Evaluation

Bob Benson

NHTSA

Ralph Hitchcock
Dick Carter

The following information was presented by NHTSA during the meeting:

- Segments of the industry believe that simple replacement of asbestos friction material with non-asbestos friction material in vehicular brakes, without regard to the effect of the change on the total brake system, may result in reduced brake effectiveness and inconsistent vehicle controllability. This would increase the risk of vehicular accidents. Other segments of the industry believe that effective non-asbestos aftermarket brake linings/pads are already available for many vehicles. There are no data available to resolve this disagreement.

- Unlike original equipment brakes, there are no federal regulations that govern the performance of aftermarket brakes. The Society of Automotive Engineers is working on performance standards that are applicable to the aftermarket. However, these standards are not mandatory or accepted by federal authorities as wholly adequate.

- Some asbestos as well as non-asbestos aftermarket brake friction products presently on the market do not perform as effectively as the counterpart original equipment product. The impact of the current use of inferior aftermarket friction materials cannot be quantified.

- In practice, there is replacement of non-asbestos friction materials with asbestos friction materials, and vice versa, without regard for the specifications of the brake system. The rate of such misapplication is unknown. However, one assumes that it may be frequent because of a lack of consumer understanding and market availability of cheap asbestos imports.

- Given the above points, a ban of the use of asbestos in the aftermarket is not expected to cause any appreciable change in the present braking performance of vehicular replacement brakes.

- Industry is already making rapid progress in replacing asbestos use in aftermarket products and several major aftermarket producers currently only supply non-asbestos aftermarket brakes. Given time, non-asbestos replacements for all brake applications could be developed. More time may be needed for some heavy trucks than for other vehicles. There may not be much incentive for persons to develop non-asbestos brakes for certain models (e.g. antique cars) because of the small size of the market.

- If EPA only prohibited production of asbestos brakes in new vehicles, while not prohibiting production of asbestos brakes in the aftermarket, some persons will continue to manufacture or import asbestos brakes for use in the aftermarket if the asbestos brakes are less expensive.

- NHTSA suggested a regulatory option that EPA may want to consider: a prohibition of asbestos in aftermarket brakes effective in seven to ten years, with a reevaluation of the feasibility of the timing of the prohibition in three years.

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NN4-28
62036

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

WASHINGTON, DC 20460

SEP 9 1988

OFFICE OF
PESTICIDES AND
TOXIC SUBSTANCES

MEMORANDUM

SUBJECT: January 12, 1988 Meeting Between EPA and NHTSA

FROM: John Rigby JR
Chemical Control Division

TO: The Record

On January 12, 1988, officials of the Environmental Protection Agency (EPA) and the National Highway Traffic Safety Administration (NHTSA) met. The group discussed the EPA rulemaking to phase out use of asbestos in friction products and the NHTSA rulemaking to revise brake safety standards. The following persons attended the meeting:

EPA

Office of Toxic Substances

Charles Elkins
John Melone
Michael Shapiro
Marty Halper
Dwain Winters
John Rigby
Lynda Priddy
Christine Augustyniak
Ed Coe
Kin Wong

Office of Policy and Program Evaluation

Bob Benson

Office of Mobile Sources

John Cabaniss

NHTSA

Ralph Hitchcock
Stan Scheiner
Duane Perrin
Dick Carter

The following information was presented during the meeting:

- There has been regular coordination between EPA and NHTSA during the past year.
- NHTSA has received a petition from the American Trucking Association asking for standards for aftermarket brakes.
- When motor vehicle manufacturers purchase brake systems, they give basic specifications to the producers, but also have a series of subjective tests. These often include on-road vehicle tests.
- It is difficult to prove that any accident was caused by the difference in performance of an aftermarket brake.
- EPA wants to coordinate closely with NHTSA to avoid any risk to safety from the phase out of asbestos in brakes. EPA also wants to coordinate the timing of any phase out with NHTSA to avoid making manufacturers redesign a vehicle twice.

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NN4-29
62036

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

WASHINGTON, DC 20460

SEP 9 1988

OFFICE OF
PESTICIDES AND
TOXIC SUBSTANCES

NN4-029

MEMORANDUM

SUBJECT: July 15, 1988 Meeting Between EPA and NHTSA

FROM: John Rigby
Chemical Control Division

TO: The Record

On July 15, 1988, officials of the Environmental Protection Agency (EPA) and the National Highway Traffic Safety Administration (NHTSA) attended the quarterly meeting between the agencies provided for in the Memorandum of Understanding. During the meeting, the group discussed, among other issues, the EPA rulemaking to phase out use of asbestos in friction products and NHTSA rulemakings to revise brake safety standards. The following persons attended the meeting:

EPA

Office of Mobile Sources

Richard Wilson
Don Zinger
John Cabaniss

Office of Toxic Substances

John Rigby

NHTSA

Barry Felrice
Ralph Hitchcock
Robert Hellmuth
Robert Shelton
Stephen Wood

NN4-031

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NN4-31

2448

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

WASHINGTON, DC 20460

10/14/88

OCT 14

OFFICE OF PESTICIDES AND TOXIC SUBSTANCES

MEMORANDUM:

SUBJECT: Telephone Call Logs

FROM: John Rigby JR
Chemical Control Division

TO: The Record

The attached are logs of telephone calls by ICF, an EPA contractor, to brakes producers. The telephone calls were to update the list of asbestos friction product producers contained in the Regulatory Impact Analysis.

See ~~ICF~~ / names company

LOC# 2449 - 2457

2487
2480

62036
NN4-31(1)

TSCA PHONE CALL LOG*

Project: Asbestos (EPA 42-321)

Name of ICF Caller: Wendy Roberts

Organization Contacted: Carlisle

Location: Ridgeway, PA

Name of Person Contacted: Bob Tami

Position of Person Contacted:

Phone Number: (814) 773-3185

Date/Time of Contact: 10/4/88, 11:00 a.m.

Questions/Responses:

Mr. Tami said that Carlisle has developed a product line of non-asbestos products. Most of the substitutes use Kevlar or mineral fibers. He is sending product literature and test data on these products. See also Log 2466

Carlisle stopped making all asbestos products in July, 1986.

* To be maintained in permanent file.

2450

62036
NN4-31(2)

TSCA PHONE CALL LOG*

Project: Asbestos (EPA 42-321)

Name of ICF Caller: Wendy Roberts

Organization Contacted: Lear Steigler Corporation

Location: Danville, KY

Name of Person Contacted:

Position of Person Contacted:

Phone Number:

Date/Time of Contact: 10/5/88

Questions/Responses:

We were unable to determine a phone number for this corporation. Directory assistance in Kentucky has no listing for the Lear Steigler Corporation and the 1988 Corporate Affiliations Directory has no listing for a brake manufacturing division or subsidiary of Lear Steigler.

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* To be maintained in permanent file.

2451

62036
NN4-31(3)

TSCA PHONE CALL LOG*

Project: Asbestos (EPA 42-321)

Name of ICF Caller: Wendy Roberts

Organization Contacted: Standco Industries

Location: Houston, TX

Name of Person Contacted: A.C. Dulaney

Position of Person Contacted: ________

Phone Number: (713) 224-6311

Date/Time of Contact: 10/4/88, 12:00 noon

Questions/Responses:

Mr. Dulaney said that Standco has developed an asbestos-substitute product for molded brake linings for both the OEM and aftermarket. However, they do <u>not</u> have a woven non-asbestos lining, so that the company still manufactures some asbestos brake products.

He requested a letter formalizing ICF's request for information. This letter was sent on October 4, 1988.

* To be maintained in permanent file.

2452

62036
NN4-31(4)

TSCA PHONE CALL LOG*

Project: Asbestos (EPA 42-321)

Name of ICF Caller: Wendy Roberts

Organization Contacted: Raymark Corporation

Location: Marshville, NC

Name of Person Contacted: Lou Williams

Position of Person Contacted:

Phone Number: (704) 624-6031

Date/Time of Contact: 10/11/88

Questions/Responses:

Mr. Williams stated that there are still some asbestos products on the line that contain asbestos. However, he estimated that the North Carolina plant, which makes friction materials, will be fully converted by early next year. This estimation depends on customer requests because many customers still request asbestos-containing products. Mr. Williams remarked that the conversion of the friction products manufactured at the North Carolina plant has gone reasonably smoothly because of the development of a glass and organic substitute material.

He suggested that I call Blaine Lowry of the Manheim, PA plant for performance data.

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* To be maintained in permanent file.

62036
NN4-31(5)

2453

TSCA PHONE CALL LOG*

Project: Asbestos (EPA 42-321)

Name of ICF Caller: Wendy Roberts

Organization Contacted: Echlin Corporation -- F.M.I. Division

Location: Massachusetts

Name of Person Contacted: E. Kaufman

Position of Person Contacted:

Phone Number: (617) 686-0200

Date/Time of Contact: 10/6/88, 10:00 a.m.

Questions/Responses:

The Echlin Corporation -- F.M.I. Division manufactures brake blocks. All products are asbestos-free, and the substitute fibers they use are NAOs.

He will be sending product literature and performance data to ICF and EPA.

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* To be maintained in permanent file.

2454

62036
NN4-31(6)

TSCA PHONE CALL LOG*

Project: Asbestos (EPA 42-321)

Name of ICF Caller: Wendy Roberts

Organization Contacted: Bendix Corporation

Location: Troy/Green Island, NY

Name of Person Contacted: Tom Buchanan/Harold Scott (Personnel)

Position of Person Contacted: Marketing/Sales

Phone Number: (518) 270-0200

Date/Time of Contact: 10/4/88, 9:30 a.m.

Questions/Responses:

Mr. Buchanan stated that there is still a demand for asbestos products in the aftermarket, although there are very few requests for the OEM. He also said that their research department is continuing to develop semi-metallic and NAO substitutes because brake linings must be designed to fit the specific weight distributions of each car or truck.

As for performance data on the substitute materials, he said that he would check with an engineer -- he thought they had some data. However, he said that the substitutes do not work as well as asbestos and the costs have doubled.

On October 6, 1988 (9:30 a.m.) -- Mr. Buchanan referred me to their public relations person (Harold Scott) who will call today.

On October 6, 1988 (12:00 noon) -- Mr. Scott called. He said he would send any available information to EPA.

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TSCA PHONE CALL LOG*

Project: Asbestos Brakes (02307-318)

Name of ICF Caller: Mark Wagner

Organization Contacted: Abex Corporation

Location: Winchester, VA

Name of Person Contacted: John Shepard

Position of Person Contacted: Research and Development

Phone Number: (703) 662-3871

Date/Time of Contact: 10/11/88, 2:00 p.m.

Questions/Responses:

Mr. Shepard stated that Abex has not manufactured, imported, or distributed asbestos-containing brakes since December 1987. Their position is that non-asbestos products can substitute for asbestos products in the OEM, as well as aftermarket segments without sacrificing braking performance. As long as similar design and performance criteria are used in developing the substitute, it will be able to replace the asbestos product currently in use.

The friction rating is one criterion of brake performance, but not the only one. Quality control standards and assembly procedures also determine actual brake performance. It is important to evaluate all of these factors when designing or testing replacement brakes (i.e., not to rely too heavily on friction performance rating that varies by product and application).

Regarding OEM specs, Mr. Shepard stated that each manufacturer requires certain levels of performance that go beyond essential safety considerations. For example, the manufacturer may require a certain noise rating or that brake pads last 100,000 miles to meet warranty requirements, but these are individual preferences and do not necessarily relate to safety. In the aftermarket, products are often grouped by comparable performance. It would not be practical for each distributor or manufacturer of replacement brake pads to provide a replacement product for each new vehicle specification. The proliferation of aftermarket products, if this were the case, would be infeasible and unnecessary. Mr. Shepard indicated that aftermarket suppliers would not jeopardize safety by standardizing the specs, but must do this to simplify purchasing for the diverse range of OEM products that need to be replaced.

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For passenger vehicles, there are two categories of friction materials: metallic or semi-metallic, and non-metallic. Within the non-metallic category there are asbestos, and non-asbestos organic (NAO) formulas. For domestic and imported cars and light trucks, the semi-metallic category for disc brake pads is growing and occupies 55-60 percent of the disc brake replacement market. Of the remaining 40-45 percent, there is currently a 50/50 split between asbestos and non-asbestos products with the trend being towards non-asbestos products. Mr. Shepard specifically stated that the substitute products worked well in systems designed to use asbestos and that the trend would continue to be a move away from asbestos products.

Mr. Shepard went on to say that the OEM and aftermarket manufacturers in the U.S. were essentially out of the asbestos market and that imports of asbestos products accounted for a large proportion of asbestos disc brake pads available in the U.S. He felt that EPA should accelerate the restrictions on imports and distribution and that this would help to alleviate what he sees as a problem.

For example, Mr. Shepard stated that he knows of one company that does not make asbestos brake products, but did import them as of a few months ago. That company is strongly against asbestos, but may be pressured into supplying the asbestos products by customers that demand them. Since it is uneconomical or impractical for domestic companies to make asbestos products due to liability and regulatory situations, it seems illogical to allow importation. If importation was restricted, substitutes would replace asbestos even more rapidly.

He does not understand why the U.S. brake companies should be under such great pressure to stop using asbestos for domestic production if importation for the aftermarket is still permissible. This is especially troublesome considering the imported asbestos products are usually low cost materials with low-end performance.

Mr. Shepard will be sending some test data, but for more information please contact him at:

Abex Corporation
Building 20
1827 Powers Ferry Road
Marietta, Georgia 30067
(404) 953-2045

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TSCA PHONE CALL LOG*

Project: Asbestos Brakes (02307-318)

Name of ICF Caller: Mark Wagner

Organization Contacted: Carlilse Corporation

Location: Ridgeway, PA

Name of Person Contacted: Bob Tami

Position of Person Contacted: Supervisor, Safety and Health

Phone Number: (804) 773-3185

Date/Time of Contact: 10/10/88, 11:00 a.m.

Questions/Responses:

Mr. Tami stated that Carlilse no longer produces asbestos brake components for the truck and heavy equipment market. They do provide, however, a wide range of substitute brake blocks that can replace asbestos brake blocks. These substitute brake blocks are available for the OEM and aftermarket segments. he stressed that Carlilse has a very diversified non-asbestos product line and that for the market segments that his company targets, there is at least one non-asbestos product that can replace the asbestos products that have been used.

The majority of applications for Carlilse substitute products are brake blocks for heavy trucks, tractors, trailers, earth movers, loaders, transit buses, school buses, delivery vans, and other medium trucks. In addition, Carlilse provides some substitute materials for disc brake pad applications, but to a lesser degree. Mr. Tami feels that the substitute disc brake pad market for trucks will grow rapidly in the near future as fleets begin to translate the experience of the brake block market to lighter trucks. He does not have enough familiarity to speculate with certainty the trend for passenger vehicles, but felt a similar pattern may begin to appear in the near future.

Mr. Tami repeated that the substitute brake blocks that they provide are intended to be replacement brakes for systems previously using asbestos-based products, but that some products were also being specified for the OEM market for certain customers.

The OEM specs are very high for all friction materials and it is important to note that replacement products, asbestos and non-asbestos, often do not meet the OEM specs. The replacement brakes do meet the government

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requirements and do not pose a safety risk. In addition, some Carlilse products have been approved for OEM specs and in fact out-perform the asbestos products that they replace. Brake blocks made from substitute materials work better than asbestos-based products in many cases for two reasons: (1) they last longer (40 to 100 percent longer) and (2) they are not as damaging to other brake components (shoes, brake drums, cam rollers, wheel seals, return springs, and bushings). As braking components are made from lighter, aluminum alloys and other materials to reduce vehicle weight, the lower abrasiveness of substitute brake blocks has become critical.

In summary, Mr. Tami firmly believes that the market for substitute friction materials will continue to grow and that these materials will be more widely accepted in the OEM and aftermarket segments.

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TSCA PHONE CALL LOG*

Project: Asbestos Brakes (02307-318)

Name of ICF Caller: Mark Wagner

Organization Contacted: American Metal Fibers

Location: Lake Forest, IL

Name of Person Contacted: Bob Carlson

Position of Person Contacted:

Phone Number: (312) 295-1200

Date/Time of Contact: 10/3/88, 10:00 a.m.

Questions/Responses:

Mr. Carlson stated that the majority of passenger vehicles are disc brake systems and that after 1975, any passenger vehicles that had drum brakes were discs in front, drums in back. The disc brakes on the latter provide most of the braking force, the drum brakes being mostly for added control and to prevent spin-outs.

Most European car brake systems are completely asbestos free. In particular, Volvo and SAAB do not use asbestos and most other manufacturers did not use asbestos in brake systems in 1988 or will discontinue by 1989 as regulations require.

In Europe, light trucks with disc or drum brakes are also moving away from asbestos linings in rapid fashion due to regulation and to the improved performance of substitutes. One major advantage of the substitute materials is that the lighter alloy drums have shown unacceptable wear with traditional asbestos linings. The substitute products not only last longer than asbestos products (up to two times as long in some cases), but brake drums also last longer.

Mr. Carlson believes that for light weight trucks, asbestos drum and disc brake linings are no longer called for in OEM specs, although he was not certain.

He also stated that the wariness expressed by producers for aftermarket substitute brakes that did not meet OEM specs was not grounded. He felt that this was only half of the story, because asbestos replacement brakes often did not meet OEM specs, either.

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He felt that the real issue was that there were no aftermarket specs for asbestos or non-asbestos products and that the hesitancy of the major car manufacturers to make replacement brakes or to specify quality was the real problem. In general, the non-asbestos replacement products are as good or better than asbestos products and do in fact meet OEM specs in some cases. The experience of his company in Europe (where "junk" linings are not sold because there are aftermarket specs) indicates that replacement products do work and that they do not present a safety risk.

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TSCA PHONE CALL LOG*

Project: Asbestos Brakes (02307-321)

Name of ICF Caller: Wendy Roberts

Organization Contacted: Allied Corporation

Location: New Jersey

Name of Person Contacted: Joel Charm

Position of Person Contacted:

Phone Number: (201) 455-4057

Date/Time of Contact: 10/12/88, 11:00 a.m.

Questions/Responses:

In response to ICF's request for additional performance data regarding non-asbestos brake substitutes, Mr. Charm sent a copy of Allied's 1986 comments on the proposed asbestos rule. Mr. Charm stated that the technology in the past 3 years has not changed significantly and, thus, Allied's 1986 comments still reflect their position and current information regarding asbestos-substitute products. Furthermore, although Allied is progressing in the development of acceptable asbestos substitute products, at this time there are not acceptable substitutes for many asbestos-containing friction products.

Mr. Charm did say that all OEM friction products are non-asbestos, as the result of customer requests. However, he felt that technology does not exist for replacing existing asbestos-containing products (aftermarket) with non-asbestos products.

Mr. Charm stated that Allied Corp. "could live with" a phase-down and phase-out in original equipment, and that the industry is going that way, anyway. However, he said that the aftermarket is far more difficult. Allied also urged EPA to build in a technology review in the rule to monitor the progress in substitute product development. Mr. Charm invited EPA to meet with Allied Corp. technical advisors to discuss these issues further.

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TSCA PHONE CALL LOG*

Project: Asbestos Brakes (02307-321)

Name of ICF Caller: Wendy Roberts

Organization Contacted: Champion Auto Stores

Location: Minneapolis, MN

Name of Person Contacted: Paul Freid

Position of Person Contacted: Marketing

Phone Number: (612) 535-5984

Date/Time of Contact: 10/12/88, 4:00 p.m.

Questions/Responses:

Questions: What changes, if any, have you seen in the use of non-asbestos products versus asbestos products?
Can a non-asbestos product be used in a system originally designed for the equivalent asbestos-containing product?

Mr. Freid stated that the use of asbestos-containing and non-asbestos containing products is directly related to the original equipment. As Mr. Freid explained, repair shops look to replace a worn-out part with a part of equal or better quality. Whether or not the product contains asbestos has not been a primary concern of Champion's customers. Likewise, cost has been an issue because many non-asbestos parts are much more expensive than the asbestos-containing counterparts. As a result, Mr. Freid felt that the replacement parts used in repair shops are usually the same type as originally on the product.

Mr. Freid thought that some products can use non-asbestos replacement parts on aftermarket products designed for the asbestos equivalent, although some applications have encountered problems with the longevity of the replacement part and accelerated wear on related components. For example, non-asbestos clutch facings are very expensive and have problems with increasing wear on other components. However, Mr. Freid said that there has been a dramatic increase in the use of non-asbestos product because of the increase in non-asbestos products on original equipment. He estimated that 50 percent of replacement parts (those that are documentable) have been non-asbestos. However, this estimate includes all applications, which may be misleading. For example, disc brake pads have been converted to non-asbestos products, but disc brake shoes do not have acceptable non-asbestos

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substitutes. In summary, Mr. Freid felt that the sale of non-asbestos products has been directly related to the parts used on original equipment. Furthermore, to avoid liability problems, repair shops prefer to replace worn-out parts with those of the same type on the OEM.

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TSCA PHONE CALL LOG*

Project: Asbestos Brakes (02307-321)

Name of ICF Caller: Mark Wagner

Organization Contacted: NAPA

Location: Atlanta, GA

Name of Person Contacted: Tom Kovtan

Position of Person Contacted: Marketing

Phone Number: (404) 956-2200

Date/Time of Contact: 10/12/88, 3:00 p.m.

Questions/Responses:

Mr. Kovtan stated that to his knowledge, NAPA corporate policy was that they did not carry any asbestos-containing products as of January 1, 1988. He suggested that I contact Joe White of Rayloc, NAPA's supplier, to get more detailed information on distribution and performance of non-asbestos versus asbestos containing brake components. Mr. White can be reached at (404) 691-3780.

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TSCA PHONE CALL LOG*

Project: Asbestos Brakes (02307-321)

Name of ICF Caller: Mark Wagner

Organization Contacted: Ozark Automotive Distributors

Location: Springfield, MO

Name of Person Contacted: Ronnie Pittman

Position of Person Contacted: Brake Parts Buyer

Phone Number: (417) 862-6708

Date/Time of Contact: 10/12/88, 4:00 p.m.

Questions/Responses:

Mr. Pittman stated that Ozark carries the Wagner brand of auto replacement parts, including brake replacement pads and linings. They carry both asbestos and non-asbestos product lines. He stated that for most applications, replacement parts performed equally well, whether they were asbestos or non-asbestos based products. Specifically, non-asbestos components could substitute, without a decrease in performance, in systems originally designed for asbestos components. In fact, most applications could use either the asbestos or non-asbestos products resulting in identical performance.

Mr. Pittman said that most purchasers demanded non-asbestos products, but that some still called for asbestos-containing replacements. It was his opinion that this was based completely on individual preference, and not performance or requirements of a given braking system. He stated that in the past two years, 80 percent of their sales for replacement brakes were for non-asbestos products, the remaining 20 percent being asbestos-containing. Prior to 1986, the reverse was the case (i.e., 80 percent of sales were for asbestos products and 20 percent non-asbestos. Mr. Pittman felt that this trend was due mainly to customer awareness of the hazard of asbestos and the growing experience with non-asbestos products that indicated that there was no loss in efficiency associated with the non-asbestos products.

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TSCA PHONE CALL LOG*

Project: Asbestos Brakes (02307-321)

Name of ICF Caller: Mark Wagner

Organization Contacted: Rayloc

Location: Atlanta, GA

Name of Person Contacted: Joe White

Position of Person Contacted: Vice President of Operations

Phone Number: (404) 691-3780

Date/Time of Contact: 10/12/88, 2:00 p.m.

Questions/Responses:

Mr. White stated that 65 percent of their brake replacement products were non-asbestos. Their premium product line is a non-asbestos product that is 17 percent higher in cost than their two other product lines (both asbestos). Their products are exclusively for passenger vehicles and light weight trucks.

Although their premium product is non-asbestos, Mr. White felt that there were possible performance and safety problems associated with the non-asbestos brake pads and shoes. He stated that they are on their fourth generation formula, but that they were still expe[illegible]ing short-comings. The major supplier for Rayloc is Abex and Abex policy is non-asbes[illegible] Mr. White s[illegible] this is the major reason that their premium product line [illegible] non-asbestos. He said that this point was important because in fact the secondary products (asbestos), even though they were [illegible] lesser grade, had marginally better performance than the premium product.

Specifically, Mr. White stated that the substitute products in their premium line had some problems associated with rear wheel lock-up and excessive noise. This is due mainly to the fact that the premium product is less forgiving than the asbestos products they are to replace. For drum brake linings their premium product shows some crazing and cracking in OEM applications that specified asbestos.

Mr. White explained that this is due mainly to the development process and the actual manufacturing technique for disc and drum brake replacement parts for passenger vehicles and some light weight trucks. Disc brake pads and drum brake linings are usually made by an extrusion process that results in a product that is not as reliable as molded or woven products used for heavy duty applications. The extruded products are manufactured so that non-

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asbestos fibers line-up in a parallel arrangement, predisposing the product to cracking. On the other hand, the extruded asbestos products have irregular fiber patterns, resulting in a more durable product.

The formulation technique for heavier duty applications (e.g., molded and woven products used in some light trucks, emergency vehicles, other fleet vehicles, and some popular vehicles) results in a sturdier product, but this technique is not used for the majority of passenger-type vehicles. formulation process is a high heat/high pressure process that provides a substitute product that is about 400 percent more expensive than comparable asbestos products, but is much more effective.

For a large fleet, costs can be cut to about 2 times as expensive as the asbestos products they replace. These products are used extensively by fleets (e.g., UPS and U.S. Postal Service) that have mandated non-asbestos products regardless of price. The major problem for these higher performance molded parts is, however, availability. Only select products for popular vehicles or specific fleet vehicles are available. Requirements for fleet vehicles account for a large proportion of sales, but higher quality products are simply not available for the vast majority of passenger vehicles.

In general, Mr. White said that they are constantly trying to develop higher performance producers, but that due to the difficulty in developing products that have a wide range of applicability, progress is somewhat erratic. He suggested I could get additional data from:

Al Indelicato
American Brake Shoe (Division of Abex)
Winchester, VA
(703) 662-3871

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TSCA PHONE CALL LOG*

Project: Asbestos Brakes (02307-321)

Name of ICF Caller: Mark Wagner

Organization Contacted: American Auto Parts Systems (APS)

Location: Winchester, VA

Name of Person Contacted: Phil Spade

Position of Person Contacted: Marketing

Phone Number: (703) 667-7800

Date/Time of Contact: 10/13/88, 4:00 p.m.

Questions/Responses:

Mr. Spade stated that APS sells both asbestos and non-asbestos disc brake pads and drum brake linings for passenger vehicles. The APS catalog lists the specific parts that can replace worn pads, shoes, or linings for given vehicle types. Their premium product is a non-asbestos replacement part, but most of their sales are asbestos-based products, roughly 95 percent. The reason for this is that most customers demand the lowest priced product (i.e., asbestos) regardless of performance characteristics.

Mr. Spade said that his experience indicated that semi-metallic pads can be used in place of asbestos pads for disc brakes and that there was no change in performance. He felt that all available products could be used in all applications with pretty much equal results, except that product life will be different. He also felt that this difference in product life would only be a safety consideration if the vehicle was not periodically inspected or examined for brake wear.

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TSCA PHONE CALL LOG*

Project: Asbestos Brakes (02307-321)

Name of ICF Caller: Mark Wagner

Organization Contacted: Allied Aftermarket

Location: East Providence, RI

Name of Person Contacted: Dave Orovitz

Position of Person Contacted: Marketing

Phone Number: (401) 434-7000

Date/Time of Contact: 10/13/88, 10:00 a.m.

Questions/Responses:

Mr. Orovitz stated that Allied Aftermarket is a division of Bendix, and that they supply Bendix replacement brake parts. Bendix policy is to replace like with like. If asbestos is used initially in a brake system component, they suggest that it be replaced with an asbestos product. The policy suggests that sales people state that there is a possibility that replacement parts that are different than the OEM materials could cause damage to the braking system.

As of August 1, 1988, Bendix launched a non-asbestos product line, but Mr. Orovitz speculates that these products only account for 1 percent of sales, at present. He also said that some of the larger fleets (e.g., UPS and the Postal Service) have decided to switch to non-asbestos products completely even if the particular vehicle system originally had been designed for asbestos components.

Regarding individual passenger car buyers, Mr. Orovitz felt that the most critical factor was price and that this was a major incentive to buy asbestos replacement parts for systems designed to accept asbestos. In order to meet the market demands of these customers, Bendix makes asbestos-containing brake replacement components at three domestic plants. The plants are located in Troy, NY, Cleveland, TN, and a third somewhere in Florida. He stated that the emissions from these plants were well controlled and that all sources of airborne asbestos were monitored.

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TSCA PHONE CALL LOG*

Project: Asbestos Brakes (02307-321)

Name of ICF Caller: Wendy Roberts

Organization Contacted: Seig-Rockford

Location: Rockford, IL

Name of Person Contacted: Dick Peterson

Position of Person Contacted: Buyer/Marketing

Phone Number: (815) 964-8631

Date/Time of Contact: 10/13/88, 11:30 a.m.

Questions/Responses:

Mr. Peterson stated that, in his opinion, there has been no increase in the use of non-asbestos in automobile replacement parts. His company's products are still based on asbestos. Mr. Peterson felt that, in general, most repair shops replace worn parts with the same type as on the original equipment. However, he added that the catalog of replacement parts does include some non-asbestos products as well as asbestos-containing products. Thus, he agreed that asbestos-containing products can be interchangeable with their non-asbestos counterparts.

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TSCA PHONE CALL LOG*

Project: Asbestos Brakes (02307-321)

Name of ICF Caller: Wendy Roberts

Organization Contacted: TPS Inc.

Location: Andalusia, AL

Name of Person Contacted: Jim Beasley

Position of Person Contacted: Buyer

Phone Number: (205) 222-7501

Date/Time of Contact: 10/13/88, 11:30 a.m.

Questions/Responses:

Mr. Beasley felt that the largest consumers of non-asbestos products are governmental agencies and some large fleets (e.g., GTE, Post Office). He could not provide any information on the trend of asbestos product use, but did say that all his warehouses carry both asbestos and non-asbestos products so that the consumer can use whichever type he/she chooses.

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TSCA PHONE CALL LOG*

Project: Asbestos Brakes (02307-321)

Name of ICF Caller: Mark Wagner

Organization Contacted: Echlin Corp. -- Brake Systems

Location: Cheshire, CT

Name of Person Contacted: John Demko

Position of Person Contacted: Technical Representative

Phone Number: (203) 271-1794

Date/Time of Contact: 10/17/88, 11:00 a.m.

Questions/Respor :

Mr. Demko stated that for almost all applications requiring friction materials, and especially for brake systems, there are non-asbestos substitute products that work as well as the original asbestos products designed to be used in the system under consideration. He also said that the popularity of these substitute materials was nil because of the higher price compared to asbestos products. He could not give exact market data, but recommended that I speak to Larry Pavey in the Marketing Division of Echlin (312-279-0500).

The replacement market for brake parts for passenger vehicles is dictated primarily by price and most non-asbestos products are more expensive than asbestos replacement parts. For this reason, individual customers usually buy asbestos products, if they have a choice. They do sell to fleet buyers, some of which require non-asbestos products, but Mr. Demko was not familiar with all of the marketing aspects.

Mr. Demko stressed that another problem with non-asbestos substitutes was the large number of different product types that are on the market. For passenger cars, he said that there were 590 different sets of lined shoes for drum brakes and 360 disc brake configurations. It is difficult for manufacturers or distributors to offer asbestos and non-asbestos replacements for all of the different types without affecting their profitability. Basically, a company cannot afford to keep a hugh inventory of substitute products that are more expensive than asbestos products.

In order to by-pass some of the perceived regulatory pressure and liability issues, some manufacturers have moved operations previously in the U.S., to Mexico or Canada. These companies produce asbestos materials of equal quality and then import them to the U.S. On the other hand, there are

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imports that may be of lesser quality coming in from South Korea, Brazil, Peru, Argentina, and other countries. Until distribution of aftermarket asbestos products are limited, these import practices will continue and there will be little incentive to develop non-asbestos products for individual passenger car brake configurations.

There is also the possibility that manufacturers will begin to produce whole OEM brake sets in Canada or Mexico in an attempt to by-pass U.S. regulations regarding import of brake pads or linings. These complete sets may not be subject to regulation and would allow the continued use of asbestos products.

Mr. Demko disagreed with AIA concerning the safety of non-asbestos replacements. He felt that although some non-asbestos substitutes would not met OEM specs, they were not a safety risk and did not pose any more of a hazard than asbestos replacement brakes. The only problem that he foresaw with a ban on asbestos was for antique cars for which substitutes had not been developed, but felt that a limited exemption could easily remedy that potential problem. In general, he felt that until asbestos products were banned there was no incentive to go to substitutes because of the price differential.

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